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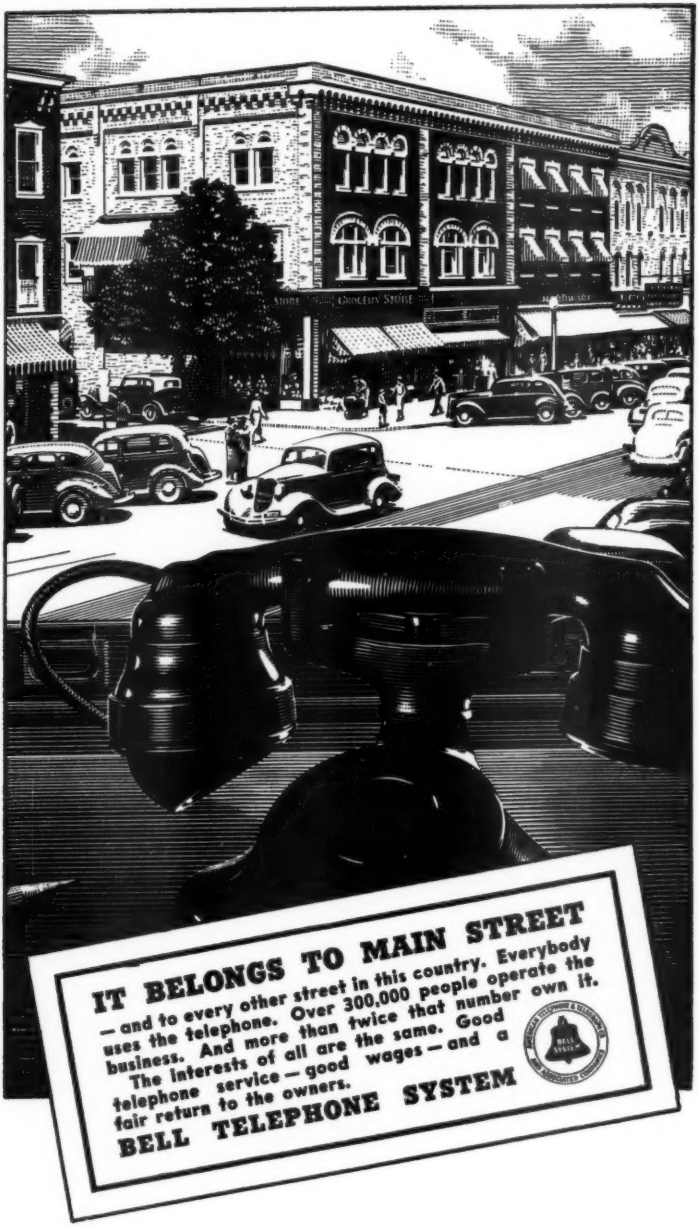

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EDITORIAL

By F. C. BOLTON, Vice President of the Society

The period represented by the life of the Society for the Promotion of Engineering Education has seen a greater progress in the application of science and scientific methods to every phase of industry than has ever occurred in any similar period in history. No engineering college expects its graduates to be familiar with all the applications of engineering even in a single field, but society demands that an engineer be well grounded at least in the theories and the principles upon which the practice in his particular field of engineering is based. With the vast increase in scientific knowledge fundamental to engineering it has been the job of the engineering educator to simplify and condense the important things in the curricula and to eliminate non-essentials in order that new subjects may be added and new ideas assimilated and at the same time to keep the curriculum within the four years that we now set as a limit. And while the young man is preparing to meet the requirements of a more complex professional life, he must bear in mind that the subject of his efforts came into this world with about the same mental capacity that his grandfather or his great grandfather brought with him two or three generations before, and certainly with no more knowledge of engineering. While success of the job has been due to the united efforts of many individuals, one of the greatest forces in unifying these efforts has been the Society for the Promotion of Engineering Education. It has been a median for the exchange of ideas on engineering teaching, with special emphasis on the teaching rather than the engineering. Many of the best features of our present-day engineering education can be traced to the papers and discussions at the meetings of the Society and to the articles published in the JOURNAL.

New problems in engineering education arise constantly. Some of them come from within but many are the result of outside influences. Social legislation limiting working hours and increased use of labor saving machinery may result in industry setting a higher age limit for young men entering their employ and thus require the educational system to absorb one or two additional years of their time. This may do more to popularize five-year curricula than educators have been able to accomplish by years of effort.

Another factor that demands the attention of engineering educators is the junior college movement which has shown such remark-

able growth in recent years and is spreading so rapidly over the entire nation. The writer is convinced that the junior college is assuming a permanent place in the educational system of America. It presents problems of assimilation which cannot be disregarded. How can the junior college and the engineering college coöperate most effectively to train young men for the engineering profession? Should the junior college confine its efforts to two years of liberal education, leaving the professional training to be given by the engineering college in three years, or should the junior college endeavor to include in its curriculum the technical subjects commonly found in the first two years of the engineering course so that the two together may offer the student the opportunity to complete his course within the established limit of four years? These and many other problems can only be solved by united effort.

While it is true that these and many others of our problems are of national import, all of them present many aspects which are sectional and lend themselves best to local consideration and solution. As such they offer material for consideration by sections and branches of the Society.

It has been the policy of the Society for the Promotion of Engineering Education to hold its annual meetings in different sections of the country. While the programs of these meetings are in no sense regional, the plan makes possible attendance by a new group of teachers each year who would be unable to attend if they had to go the greater distances. The meeting at College Station, Texas, in 1938 should make possible the attendance of all active, alert engineering teachers, particularly in the South, the middle West and on the Pacific Coast, who have not found it possible to attend the meetings at more remote points. In years when the National meeting is held at a part of the nation, where members, who, by reason of distance, are not able to attend, these members should not neglect membership in their local sections and branches and the opportunity to participate in their meetings. Mingling with others in our profession must surely broaden our views and increase our enthusiasm for our work to say nothing of the more tangible profits to be gathered from discussions of the topics on the program. Let each of us plan an active participation in the work of the Society this year.

PRACTICAL OUTCOMES OF THE STUDY OF EDUCATION SINCE 1900 *

By H. W. HOLMES

Harvard University

Educational problems have been studied more widely, intensively and enthusiastically in the United States since 1900 than anywhere else or during any other period in the history of the world. Now, of course, this does not mean that they have not been studied elsewhere, too. One could make a very interesting story concerning the study of education in other countries. If one were speaking of Germany, he would have to speak of the great work that has been done in the history of education and also in the general theory of education, and in talking to engineers or any other body of educators interested in a vocation, one would have to mention Georg Kerschensteiner, who was probably the greatest exponent of the idea of vocational education. Then one could mention France and Switzerland and talk of Compayré and Claparède and now Piaget and others. In England, one could mention Sir John Adams and Percy Nunn and others. But on the whole, in spite of the great figures in the field of education in other countries, it remains true that in the United States more attention, more zealous, hopeful and definite attention, has been given to the study of education than anywhere else in the world and more since 1900 than at any other time in the history of the world.

That does not commit one to saying anything about the actual accomplishments of all this work, but a very real amount of achievement that will stand and on which we may build has actually accrued from it. I think it is one of the consequences of the democratic form of life and of government in this country, a consequence that was fairly late in showing itself but which has a direct connection with the fact that a democracy necessarily depends upon an educational system which is widespread and effective.

Of course, there was some work in education in this country before 1900. The great figures that one hears spoken of, Horace Mann, Henry Barnard, W. T. Harris, and slightly before 1900, Charles De Garmo and G. Stanley Hall, perhaps make a sufficient galaxy in themselves; but those names had all passed into the his-

* Presented at the 45th Annual Meeting, S. P. E. E., Cambridge, Mass., June 28–July 2, 1937.

tory of education before the beginning of the time of which I am speaking and it remains true that since 1900 more work of wider scope and greater intensity and enthusiasm has been accomplished than ever before.

With respect to the relation between education and democracy, I ought to say that I honestly believe that the American faith in education, as a result of the democratic form of life and government in this country, is the root of our enthusiastic attention to educational problems. That faith may have some falsity in it. The notion that we can achieve anything like a real equality among men, that every boy ought to nourish the hope that he will be President or at least a Rockefeller, that notion may be entirely false. It does not find support in the work in education of which I am about to speak. Nevertheless, there is a root, a germ, in that democratic faith that has been a powerful factor in stimulating the study of education and bringing about the achievements in the schools of this country that have resulted or have accompanied the study of education.

Besides the teachers' colleges of America (this is one evidence of the extent of the study of education), every important university in the country except one has some department, school, or college devoted to the study of education and the training of teachers and school officers. Of course, there may be too many. No doubt there ought to be better ones and fewer, and there is certainly too much localism in education, but the fact that I have just spoken of does show the extent to which the study of education has spread, because nearly all this growth has come, this growth in the schools of education, departments of education and work for the training of teachers, since 1900. This rapid growth has been due to many causes, among the most important of which is the pressure of population on the schools. Just before 1900, there were fewer than three hundred thousand pupils in the secondary schools of this country. In 1880, there were only 110,277 pupils in the secondary schools in the country. Now, there are about six and a half million. The enrollment in colleges has increased manyfold. The depression has reinforced this movement into the schools. It began because wealth had mounted and the frontier disappeared, and hence people had begun to want more education for their children and to be able to pay for it; it has continued because jobs have not been open to young people. Furthermore, the number of adults and old people in relation to the number of children and young people has very greatly increased. The detailed story of that change, that shift in population, can be found in the book by C. H. Judd called "Problems of Education in the United States."

And all these facts, together with the development of psychology, sociology, and other sciences of human life, and the natural democratic concern for education, inevitably stimulated the study of educational problems.

The study of education in the United States cannot be said to have resulted in a better educational system than other countries possess. It would be a bold defender of American education who should say that our educational system, as a system, nationally considered, is better than the system of any other civilized country. Nor can it be said that this wide-spread study of educational problems has resulted in a highly developed science of education. Whether we have a better system of education than other countries depends on what conception of national aims in education the judge in that matter chooses to adopt. We have paid too little attention to the unity, continuity, and coherence of our programs of study.

However, it seems to me that on the whole it is fair to say that because of the present situation in America, with the pressure of population on the schools, with the tremendous expenditure of money, energy, and enthusiasm in school work, accompanied by an increasing amount of critical study of educational problems, we are in a more promising position than older countries where the whole educational system is fixed far more than it is here; where the whole situation is less fluid and much less attention is being given to the analysis of educational problems and their proper solution from every point of view. We have not a well-developed science of education but we have more than an incipient science of education.

When I first turned to the study of education in 1902, Professor Paul A. Hanus used to refer to the science of education as incipient and he emphasized the fact that it was only incipient. Well, that depends on your time scale, but I am inclined to believe that it has "incipped" a little since 1902.

The study of education and educational effort in general in this country must be admitted, I believe, to have resulted in a considerable amount of wasted effort, superficial discussion, and in the end, "pedagogical racketeering." State requirements of courses in education for teachers' credits (in educational psychology, the history of education, the philosophy of education, secondary education, general methods and special methods) and the resulting rush for "points" in these things and for degrees made up of credits and points—all that has led to a great deal of very perfunctory and superficial work. There has been, in the getting of degrees in education, a good deal of "cafeteria" education, where you go in and look over the offerings, pick up any unselected bunch of credits that you happen to want or can get at convenient hours,

put them all together, get a passing mark in them and get a degree. But I think we should not be unduly haughty about that sort of thing. Thousands of teachers, even with a good deal of wasted time, have improved their skill, got new insights and new outlooks, and finally settled down to use some of these things effectively and practically when a little of their early, more superficial enthusiasm had worn off.

It does seem to me, however, that the time has come to bring into the study of education and the training of teachers a more honest, unified, and continuous program of courses and a greater solidity and substantiality of effort in the teaching of those courses and of standards therein. But I should get off into something in which you probably have little interest if I followed that line. What I want to emphasize is, instead, the fact that all this study of education, in spite of its defects, has some important practical outcomes. It would be asking, I think, too much to expect the establishment of a science in such a complex and difficult field within forty years. Furthermore, it is only very recently that any disposition has developed among scholars and research workers in other fields to coöperate with students of education and professors of education. The latter were at first not very welcome in the learned world and they have consequently held themselves somewhat aloof. I think that is a perfectly natural and simple thing. A professor of education is inevitably a prophet in his own country. He has come into the university to study what the university is doing. He may sedulously keep his eyes on those terrible schools out there in the distance, but he will inevitably be suspected of having some intention also of thinking about his own colleagues and what they are doing, namely, teaching. Of course he will; and so he is inevitably looked upon askance—or was before the university got a little used to having him around and found that he was not such a terrible fellow after all.

When Professor George H. Palmer first met Professor Hanus in 1891, Hanus having come to Harvard as one of the first professors of education in the country (and he was not called a professor of education but a professor of the history and art of teaching), Professor Palmer said to him, "Ah, Professor Hanus, you have come from the West to teach us how to teach. Isn't that nice!" And when I first met Professor Palmer in the faculty room of University Hall, he said, "Ah, Mr. Holmes, you have come to assist Professor Hanus. That is very nice! When Professor Hanus came here, he bore the onus of his subject; but now there is no one whose voice is listened to in the faculty with greater respect." Well, Professor Hanus told me that Professor Palmer was right about bearing the onus of his subject, but as to the rest of it, he wasn't so sure.

But the universities are beginning to get used to the fact that they ought to turn their eyes inward upon themselves and the system of which they are a part and study problems of education. The engineering divisions have boldly, for many years now, said that they are going to study their own teaching processes and they have done so and have even played a little with professors of education recently, so the thing is getting a bit more habitual and I think it will work out so that professors of education will not be looked upon with quite so much suspicion as formerly and perhaps will even begin to play with and be asked to play with their brethren in other departments of the university.

Seriously, it seems to me that since education is a subject which has to depend upon the fruits of the labors of many, many men in many fields, it is to be expected that it will develop more soundly and fruitfully when all the resources of our universities can be converged on the study of educational problems and that, I believe, is now coming on.

At Chicago and at Harvard, the training of teachers for secondary schools has now become a university instead of a departmental undertaking, and that is a very promising sign. I hope that it may happen here that in training teachers for technical schools, such as the Rindge Technical School or the Wentworth Institute, on the secondary level, the School of Education at Harvard and the School of Engineering at Harvard may find a way to coöperate.

There are at least three major fields in which it is possible to point to important practical outcomes of the study of education since 1900. In each of these fields, the study of education is moving forward toward the solution of broader and more complicated problems.

First, in the psychological study of education, veritable triumphs have been won. I think that is not too strong a statement. Intelligence testing, established on a practical basis by the French psychologist Binet in 1905, has been developed in this country until it is an effective means for the determination of feebleminded-ness, for the classification of normal and gifted children in schools, for the study of methods of teaching, and for the diagnosis of individual difficulties in learning.

I suppose that a body of this kind, a body of engineers, does not need to have explained to it the meaning of the conception of mental age, intelligence quotient, or any of the essential elements in the business of general intelligence tests. I will not take time to bring coals to Newcastle, but I would urge any of you who have doubts as to the value of intelligence testing, or who wonder whether a good deal of harm is not done by the use of intelligence tests, or

who wonder what, after all, is the use of getting an IQ for a child, to look into the literature on that subject. Professor Dearborn's book on "Intelligence Tests; Their Meaning for School and Society," is a good recent summary of the whole problem of intelligence testing, dealing with its limitations as well as its possibilities and uses.

Those who have dealt with the results of intelligence testing and who have studied the problems of testing the intelligence of children, are wholly confident that we rounded a corner when Binet and Simon developed the scale for testing intelligence in children; that we got to a new level; that we can do things in education now that we could not do before; that we passed a critical point very much like that which the doctors passed when the clinical thermometer was invented. We have a means of getting some measure, and a fairly reliable and valid measure for various purposes, of the general intelligence of children.

It was H. H. Goddard of the School for the Feebleminded at Vineland, New Jersey, who brought the Binet scale to America and who published an American revision of it in 1911. F. Kuhlman published another in the same year and the most widely used American revision of the Binet intelligence scale was produced at Stanford by L. M. Terman and his associates in 1912. The Stanford revision has just come out in a new form. The book that gives the Stanford revision and the directions for administering it is probably the best source for finding what a general intelligence test actually is. If any of you are curious to get at the thing itself, that is the place to find it, the 1937 revision of the Stanford General Intelligence Test published by Houghton, Mifflin and Company under the authorship of L. M. Terman.

Intelligence testing plays an increasingly important part in educational and vocational guidance. Any serious attempt to guide groups of children, or any child, without the use of intelligence tests, is half-baked. It is not a serious and valid attempt. While I am mentioning educational and vocational guidance, I ought to say that this field of educational effort has grown increasingly in importance and has come to be recognized as fully as deserving of attention as the field of instruction itself. How to get children into the right courses and through the right courses into the right work in life is perhaps the fundamental problem of education. Of course, once you have got them into the right courses, you have got to teach them in those courses and they have got to be willing to be taught and there are plenty of problems of instruction and of general treatment of children, what one can call in a large sense the discipline of children, even after guidance has done its work, but a field that we had not entered before 1908 and that we have entered

since and which has expanded and grown under our inspection, is the field of guidance.

There has been a great deal of charlatanry in the field; there has been a great deal of talk that has not been matched by any important doing; there has been a good deal of pretense and in engineering I think you know that in some quarters there has been a decided pretense that you could choose an engineer, even when he was in the kindergarten, by specific tests. There ought to be a great deal of caution about believing that it is possible to detect future successful lawyers, artists, engineers, musicians, clergymen, doctors, by testing early in life. The thing is not as simple as all that; but the study of guidance has now progressed to the point where it can be done with the aid of scientific instruments, that is, instruments of exactitude, of greater exactitude than we ever had before, and it is actually being done in some school systems and in some schools effectively enough to make the whole picture, the actual result, very different and very much better than it could possibly have been before 1900.

Professor Dearborn of the Harvard Graduate School of Education has developed non-linguistic intelligence tests, both individual and in group form, which are capable of doing on a non-linguistic basis, or largely on a non-linguistic basis, what the Binet intelligence tests do with a great deal of reliance on language, so it is possible to distinguish various types of mentality and measure their growth. That is an important advance in the whole undertaking.

Meanwhile, standardized tests of school achievement have also developed. They grew out of the work of Dr. J. M. Rice, Superintendent of Schools in Baltimore, in the year 1894. Rice went to Germany and came back with the idea of attempting to develop a science of education. He started in by actually testing children to see whether or not they could spell; and then he developed the idea of studying methods by exact observations as to the result of methods. It is amusing now to look back on the reception that those efforts of Rice had. When he told the Department of Superintendence of the National Education Association in February, 1897, about his tests of spelling in the schools and his conclusions based on those tests, he was laughed out of court. L. P. Ayres wrote about Rice's appearance at the convention as follows:

"The superintendents were united in denouncing as foolish, reprehensible and from every point of view, indefensible, the effort to discover anything about the value of the teaching of spelling by finding out whether or not the children could spell."

That was in 1897. Since that time, standardized tests have developed into a very effective measure for the study, not only of

the immediate results of educational processes, but of educational problems. It was all very much stimulated by the theoretical and practical work of E. L. Thorndike of Columbia University. He published in 1904 his introduction to the theory of mental and social measurements. In 1909, he published the first scale for the measurement of any educational product. It was a scale for the measurement of handwriting.

After that came various tests in rapid succession. In 1908 and 1909, tests by Stone and Curtis; and tests by Ayres in 1917; and also in 1917, one of the most effective of the earlier books in the field of measurement, Ruggs' "Statistical Methods Applied to Education."

All this has led to a remarkable record of growing usefulness in the study and treatment of individual differences in education, a growing usefulness for standardized tests. Meanwhile, studies in the laboratory, theoretical analyses of the processes of learning, experimental work in schools and programs of testing in schools and colleges, have led, first, to the diagnosis of individual difficulties in learning and to remedial treatment, as in reading.

I want to pause just a moment on that. If any of you have a child of your own or know of a child who reads slowly or finds difficulty in reading, and who is otherwise, so far as you know, an intelligent child, do not assume that that is something final, that it cannot be helped. Intensive laboratory studies involving photographic records of the movements of the eye in reading, very careful scientific analyses of the sources of difficulty in reading, have led to the development of remedial methods in getting children to read, to help them along, when the children have reasonable intelligence, that are decidedly, in many cases, effective. They are not, to be sure, effective in every case. Some of the difficulties are due to causes that are very deep-seated, such as a difference in the size of retinal images as between the two eyes, something that may be difficult to find out and hard to correct. Hence it is not sure that the remedial methods that have been developed will be effective; yet it is safe to say that many of the difficulties in reading that arise in the cases of normally intelligent children are not permanent and can be partly or wholly removed.

Here is an example of the genuinely scientific study of an educational problem—the study of reading difficulty. It has been done in three centers, in Chicago, in New York and here in Cambridge. Professor W. F. Dearborn of the School of Education, in his laboratory studies of reading, has, I suppose, done as much as anyone in the country in that field.

The second thing that laboratory study and theoretical analysis and experimental work and so on have led to is the general improve-

ment of teaching technique. Those would be more apparent, very much more apparent, if there had not been so very much more teaching to do as the schools have developed since 1900. We have had to turn into the work of teaching a good many raw recruits who had not been well drilled.

The third thing these studies have led to is the partial abandonment of purely subjective estimates (that is, teachers' marks) of educational accomplishment and the substitution for them of objective tests such as scholastic aptitude tests for college entrance and actual measures of achievement within a given subject. For example, consider the growth of vocabulary in foreign languages. Teachers' marks, as you probably all know, are thoroughly unreliable. It is fair to say that instruments have been developed and knowledge accumulated which make it possible to classify, teach, and guide individual pupils in schools and colleges with an approach toward scientific accuracy. What is chiefly needed is the training of all teachers and school officers in the uses and limitations of the instruments and knowledge already available, together with further creative work in this field.

The twelve-year study of the physical, mental and scholastic development of several thousand individual school children which has been recently completed by Professor Dearborn of the Harvard School of Education, and by his associates, is the first study of that kind ever undertaken in the world. Nobody every studied several thousand of the same children, measuring their intelligence, their physical dimensions of various kinds, and their scholastic growth from year to year through a twelve-year period. Why not? Because it was never possible before. There were no measures. There were physical measures but there were no measures of the growth of intelligence or of scholastic achievement that would enable us to get exact, comparative measures of the same children over twelve years, before 1900.

Now that has been done. That body of data is about to be published. It is certainly unique in the whole world. We will know at least how three thousand children around here grew, and what the individual course of their development was, whether there are any typical courses of development. That has now been done with precision. It could never have been done before 1900. Even more comprehensive studies are needed, using even more refined instruments.

I said there were three fields. I have been talking about the psychological study of education, chiefly the work in the field of measurement in education. The second field is the field of studies of the curriculum. These have not been quite so fruitful as have studies of individual intelligence and individual learning. Never-

theless, they have settled some fundamental issues. In 1900, the schools and colleges of the country were still working under the influence of the first American study of the curriculum, that of the Committee of Ten appointed by the National Educational Association in 1892. President Eliot was its Chairman. The Committee recommended against differentiated curricula and considered the value of studies largely in terms of their supposed effect in training "the powers of the mind." The report, so far as it was effective in preventing the development of special curricula to meet special needs, including vocational curricula, and so far as it perpetuated the false notion that subjects are to be chosen for their value as disciplines for the mental faculties, was profoundly unfortunate. I suppose it actually set back the progress of American schools and American college instruction by several years, but nobody knew that it was going to do so. The body of people who made the report, the Committee of Ten, was highly distinguished. There was no educational knowledge on which they could base their findings and they theorized about what subjects could do for the mind and laid down a program based, as I have said, on the notion that subjects are to be chosen for what they do to the mind and not for what the mind does with them, and based also on the notion that it was possible to have a uniform curriculum in secondary schools of the country for all children of all groups.

The Commission on the Reorganization of Secondary Education, reporting in 1918, shifted attention to the concrete social outcomes of secondary education, such as preparation for vocations, for homemaking, for citizenship, for the worthy use of leisure. The Federal Board for Vocational Education was established in 1917. The American Council on Education was organized in 1918. These were moves away from that stand for uniformity and for an unrealistic approach to education which characterized the work of the Committee of Ten. The General Education Board, the Carnegie Foundation for the Advancement of Teaching, the Commonwealth Fund and other bodies have financed from time to time since the war, general and special studies of the curriculum: The Modern Language Study, the Classical Investigation, and other studies of the same sort, and the monumental study of the relation between secondary schools and colleges in Pennsylvania, conducted by the Carnegie Foundation for the Advancement of Teaching under Dr. W. S. Learned. The most recent report of a national committee is that of the Committee on the Orientation of Secondary Education, of which Professor T. H. Briggs of Teachers College was Chairman, which has shifted the whole basis of curricula studies to major issues of national policy, such as the issue of making secondary education universal.

The older studies of the curriculum looked upon the whole problem of curriculum-making as if it were in a vacuum. They did not think of the resources available, of the types of pupils to be taught, or of any of the actual surrounding conditions which affect the problem. They thought of studies and minds as if one could be matched with the other, irrespective of the interferences that might affect the process.

Meanwhile, the national survey of secondary education under the auspices of the United States Office of Education, when W. H. Cooper was Commissioner, was completed in 1932. Books and articles on the curriculum have appeared in large and increasing numbers. The junior high school and the junior college have developed. There were about five hundred junior colleges in 1931, with a hundred thousand pupils in them. There must be many more now.

The Progressive Education Association has appeared as the recognized organization for leadership in a vital movement originated by John Dewey before 1900. The total effect of this activity in the field of the curriculum is difficult to summarize, but it may safely be said that no informed person any longer supposes that school or college curricula can be uniform, that studies can be selected on the basis of their supposed values as mental discipline, that a valuable curriculum can be organized by choosing elective units or credits without continuity, coherence, or a definite object, or that the values of subjects can be attained without reference to their organization in a curriculum, the excellence of the teaching devoted to them, the ability and interests of the pupils who study them, and the general life and character of the school in which they are taught. Studies of the curriculum have broadened. The depression and C.C.C. camps have raised new problems.

The Committee of Ten thought of each subject more or less in the abstract, in reference to a mythical average mind. Students of the curriculum now center their thought on the total education of real and differing groups—children and young people of varying intelligence, varying backgrounds, and varying vocational interests. Vocational education, vocational and educational guidance, and extra-curricular activities all come into the picture. The curriculum widens out beyond the schools.

Third and last, studies of general administrative problems have settled perhaps fewer issues, but they have not been less important in the nature of the questions they have attacked or in some cases, in their effects. City school systems and state departments of education have made administrative studies of much value for their own areas.

I would like to call your attention to one which seems to me unique. It is the Niagara Falls Report, made by a committee headed by Dr. F. E. Spaulding, then of Yale, for the New York State Economic Council. It was motivated, as far as the Council was concerned, by a desire to find out whether there was much waste of money in a typical New York city educational system and the city of Niagara Falls offered itself as the subject of study. Dr. Spaulding and his committee did not carry out an elaborate survey of Niagara Falls, but they went into the system to see in a general fashion whether it appeared that, on the whole, the work of the schools was effective or wasteful. In the Niagara Falls Report, which can be obtained from the New York State Economic Council in New York City, Dr. Spaulding presented a balance sheet of an American city school system that is enlightening. One of his fundamental conclusions was that in American schools we have too much teaching and too little learning; that we try to teach too many things to children without getting them to address themselves eagerly and effectively to the learning of much that we try to teach them. That is just a sample or rather an unusual sample, of a city school survey, administrative in character, but getting into the heart of the educational process.

The present monumental study of education in New York State, which is being conducted under the Board of Regents of that state, is likely, I believe, to yield results of very great general value. It will involve a study of elementary schools, of secondary schools, and of schools for the training of teachers and will also go into administrative and financial problems.

Departments of research in city systems date from 1912, when such a department was established in Baltimore. School surveys began with the Pittsburgh survey in 1907. The study of administrative problems in education has been centered partly on questions of finance, partly on questions of efficiency in general management; but it is inevitable that when one studies the problem of economy in education, or of efficiency in education, one should get into the actual content of what is taught and the actual results of what is learned. One early result of studies of administrative problems was the establishment of the idea that a small unpaid school board, appointed or elected at large, working without subcommittees, through a paid professional expert advisor, the Superintendent of Schools, constitutes the best organization for an American local school system.

Another result is the establishment of certain facts about financial support, to wit, that education is a state function although best managed in the main by localities, but that equality of opportunity is impossible of accomplishment as among localities unless

the state supplements local resources and equally impossible among states without national aid. State equalization funds have been achieved, but no general Federal aid. Federal activity in education, although studied exhaustively since the war, remains unsystematic and uncoördinated.

Dr. Henry Suzzallo, before he assumed the presidency of the Carnegie Foundation for the Advancement of Teaching, headed a committee which made an extended study of the problem of national action in education. It was called the Committee on National Action in Education. Dr. Paul R. Mort and Professor Norton of Teachers College have just published two books that really go into the very root of the matter of federal action. Paul Mort's book is "Federal Support for Public Education," published by the Bureau of Publications of Teachers College, Columbia University, in 1936. Professor Norton's book is "Wealth, Children and Education," published by the Bureau of Publications of Teachers College in 1937.

The President has just appointed a commission to advise with him with respect to Federal action in education. Professor F. W. Reeves, of the University of Chicago, is chairman of that Commission and Dr. Payson Smith, of the Harvard Faculty of Education, is a member of it. I hope that some actual results in determining Federal policies in education, which now just ride off in all directions at once, will come out of the work of this body.

In these three fields, then, as well as in others, the problems of education have been subjected to direct and profitable attack. Meanwhile, the history of education and the philosophy or general theory of education, have made real advances. The comparative study of national systems of schools is a recent and highly promising development.

This whole situation in the study of education, as it has developed since 1900, would be extremely hopeful except for one ominous fact: Political interference with the schools is to-day more widespread, more cynical and more sinister than ever before. The need for teachers and school officers who have achieved a genuine understanding of the professional materials available for their use cannot be over-emphasized; but if unqualified persons are given preferment for political reasons and competent public servants dismissed without cause and without hearing, what is likely to become of education as a public service?

Discussion

C. J. Freund (University of Detroit): Is there available for the use of men teaching in a profession like engineering, some short-cut to this business of teaching-technique? I know what the

ordinary engineering educator thinks of pedagogy. It seems to me that when a group of people in a field such as education have worked as many years as they have to accumulate a great deal of information, we ought to take advantage of it.

This obvious difficulty presents itself immediately: You cannot learn to teach as well as you think a man ought to teach, as far as teaching technique is concerned, and at the same time in a single lifetime, learn enough to teach. After all, our principal business is to teach engineering but your remarks suggest that there may be some way whereby we can, while leaving the bulk of our efforts in the professional field, sip a little bit of this big resource of teaching effectiveness and make our engineering teaching better without going with our whole effort into that area.

Dean Holmes: Well, Dean Freund, I ought not to have given out the suggestion that there is any way in which you can improve your effectiveness as teachers by taking a pill. I do not know of any little summary of the thing, a sort of book of rules, or any way of getting it. Those lectures of Professor Spaulding's, which this Society published, seem to me the best specific summary of the problems of teaching technique that I have ever seen in short compass. He gave these lectures specifically for the purpose of trying to suggest what could be done by a teacher of engineering to improve his own technique, acting on the basis of principles rather than following rules of thumb, that is, taking an idea and trying it out in his procedure.

For example, take the whole notion of motivation. Spaulding deals with that in his lectures and I do not want to repeat what he says, but it is quite possible that anyone who feels that his teaching is not as effective as it ought to be, who knows he knows his subject but somehow feels as if it is not going as well as it should, —it is quite possible that what he is neglecting is the business of motivating his students, getting them interested, and that he has not tried enough ways to do it. Well, you cannot tell him the answer. It depends on his students, it depends upon the situation, and on him. Some things will work well for one man and some for another, but here is a possibility, here is a whole area of the business, namely, motivating students, getting them on their toes somehow. Perhaps the school does not motivate them, perhaps it puts them into a balky, hanging-back attitude and the teacher will have to do something himself. What, nobody can say in advance, but he can find out if he will try first one thing and then another.

In a study of the Harvard Department of Economics, conducted by the Division of Education before it became a School of Education, I myself wrote a chapter on teaching, with a long list of possibilities under such heads as motivation. That might be

interesting to anyone who wanted to look it up in the library. That study was made in 1916 and it was about the teaching of Economics and I cannot recommend it as a general textbook on method, but it did have an actual listing of the elements in effective teaching. I do not mean that it tells you the thing to do, but it does list the things about which you should try to find out what to do. That is another source; but I think Spaulding is the best.

Louis O'Shaughnessy (Virginia Polytechnic Institute): I should like to know if we have any statistics based upon the effect of placement tests on student mortality and, if so, whether they have shown any reduction in student mortality which may be directly attributed to the use of placement tests.

Dean Holmes: I regret to say that I have no statistics which can show the extent to which placement tests have saved the lives of students. I cannot give you any factual evidence on that whatsoever. I am, of course, wholly convinced that the whole process of guidance, not merely placement tests but the whole process of guidance, when successfully carried out, prevents a good deal of misfortune and perhaps mortality to students. I suppose this ought to be admitted, however, in the face of the best that can be done by the science of education with respect to the guidance of students, namely, that there will nevertheless be, because the world is the world and human beings are human beings, some mortality and some misfortune. We cannot get everybody into the right place by any possibility. There are some people who would not let us if we could, so we have got to make up our minds that in the total army of humanity on the march, there are going to be stragglers and lost souls of one kind or another; but we can do a great deal more than we used to, at any rate.

ADMINISTERING THE FACULTY*

By WILLIAM O. HOTCHKISS

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Introductory Remarks

Before I begin this very brief and comprehensive paper, I want to congratulate this group on their interest in the topic which Dean H. W. Holmes of Harvard University just presented, *i.e.*, Practical Outcomes of the Study of Education Since 1900.

One of the difficulties of a president in administering a faculty is to secure the proper kind of faculty to administer and I think the engineers of the country are to be congratulated on the interest which this body has taken in the matter of engineering education. That there is such a large group here is something for which you people should be congratulated and on which the engineering profession as a whole is to be congratulated.

There is no royal road to teaching, and I had the advantage, if there was any advantage in it, of two years of normal school training for which I never could see much advantage in any of my teaching. But there is a divine fire that burns in the souls of some men to teach and fortunate indeed are the students who have the privilege of working under those men. That divine fire is not spontaneous combustion. It has to be ignited and attendance at these meetings—I do not mean here but attendance in general at the meetings of the Society for the Promotion of Engineering Education—is one of the best means there is of igniting that which every teacher needs to have burning in his soul.

Oftentimes I find that the dictionary is a valuable source of ideas. Sometimes I am rewarded by finding something pleasantly humorous when I look up a word. So the first step in preparing this paper was to look up the word "administer." I found a gamut of meanings that covered all the various kinds of administrative policy with which I have come in contact. The first meaning given is general—"To manage or conduct; to direct or superintend." The second meaning is "To dispense; to serve out; to supply." The third meaning gave me a bit of amusement as it reflected so well the opinion I have heard some faculty men express as the purpose they imputed to the administration; "To apply, as

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medicine or a remedy; to give, as a dose of something beneficial or suitable. Hence, by extension, used of a blow, reproof, or the like." This third meaning was illustrated by a quotation from Smollett—"A tweak of the nose, administered by the tar who stood sentinel over us."

Administering a faculty is not essentially different from managing a large business in which there are many men of exceptional ability. I have known of large corporations, and faculties, administered on the dictorial basis well expressed by the comedians rule for managing wives which was current a few years ago—"Catch 'em young, treat 'em rough, tell 'em nothing." I have seen such corporations and faculties prosper and excel under such administrations. It is an old saying that a wise benevolent dictatorship is the best form of government. The difficulties with this are first to find the wise benevolent dictator, and second to find his successor. The usual result of such an administration is the discouragement of initiative on the part of subordinates. Everything is left to the decision of the superman at the head. When he passes out of the picture, there is no one developed to take his place and the ship of state flounders pitifully and, in many cases, runs on the rocks. I do not consider that a business run on this basis is a good investment for our endowment funds. Neither do I consider that a faculty run on this basis is a good educational investment.

I have reiterated to the faculty of Rensselaer Polytechnic Institute that I do not know enough to run that institution as it should be run. I have defended my protestation of ignorance by adding that, in my opinion, neither does anyone else know enough to run it as it should be; that only by the combined best judgment of all of us can our aims be accomplished; that without effective, constructive teamwork by the whole faculty, from the youngest instructor to the oldest department head, we cannot do what we ought to do.

The cultivating and stimulating of this spirit of teamwork in the faculty, the student body, the alumni, and the trustees, I consider to be the chief job of the one who is to administer most successfully an educational institution. The accomplishment of this end requires clear vision, both on the part of the administrator and on the part of the faculty, of the purposes we desire to accomplish. It requires free and untrammelled debate by the faculty as to what are their purposes and what are the devices most useful to accomplish them.

Generally stated, the purposes of adminstration are:

To promote the development of professional leaders and well-trained subordinates, and

To provide a faculty suitable for this purpose.

In planning for the accomplishment of these purposes, the first thing an administrator should do is to take stock of himself. He should clearly understand his own points of strength and weakness, the fullness and meagerness of his experience in various lines of activity. He should know or find where to turn to get the best advice on all matters and particularly in those lines where his experience is meager or lacking. He should possess and cultivate an increasing capacity of patience, so that he may be content to take the time requisite for the real and permanent upbuilding of the understanding of his faculty.

He should take stock himself and inspire the faculty also to take stock of the needs of society in general, and of industry in particular, so that all may be aware of the particular kinds of training that will best fit students to meet the needs of their times. This should be a continuing policy. It may be carried out under the direction of a general committee, guiding the efforts of departmental subcommittees in the studies of their particular fields.

Based upon the results of such continuing studies of needs, there will follow naturally the continuing revision of the curriculum designed to meet these needs. Only after the survey of such needs, can intelligent results be secured by the hard-working members of the curriculum committee. In these days of rapid change in technical applications, a curriculum or an individual course that has not been subjected to material revision in the last five years is almost sure to be out of date. Even mathematics, chemistry, and physics courses—the foundation sciences on which all our engineering thought is based—can be revised frequently with much profit if due thought is given to the needs to be served.

Applied engineering courses have grown in quantity until most curricula are burdened to the verge of foundering. The successful administrator must provide the means and the stimulus that will insure in the faculty a broad view of the whole field and a balanced vision that will permit the wise selection of the most important and the even wiser elimination of those useful, but relatively less important items that are in so many instances included in present curricula.

Another thing that a successful administrator must do is to correlate the aims of the faculty with the financial possibilities of the budget. Many things are, in themselves, of great value and most desirable. The number of these worthy things appealing for a place in the budget is greater than can be permitted in even the most wealthy institution. The ideal administrator should be possessed of the ability of Walter H. Page. It was said of him that he could refuse a manuscript so tactfully that the author was almost as well satisfied as though his work had been accepted.

The particular fields of activity in any institution should be limited to those in which they can do the best work. Both personnel and funds must be considered in choosing these fields.

An ideal faculty—lik. an ideal administrator—I fear never existed. Few, if any of us, have had all the opportunities to develop that which is needed to bring out the maximum of our abilities. We all grow and develop with the acceptance and meeting of responsibilities put upon us. We fail to develop if we have no responsibilities. Without steadily increasing responsibilities that stimulate his interest and give him confidence in himself, an instructor is like the rich man's son who does not have to work. He fails to develop his latent powers under the compulsion of necessity.

In administering a faculty, I believe the most important thing is to provide an increasing load of responsibility for the younger men just as rapidly as their ability will permit. Insofar as the administrator accomplishes this, will he succeed in developing first-rate men. This does not make for an easy life for the administrator. It is much easier to put a man in a groove and hold him there as a mere routine worker. Many a teacher is willing to do this. A well-developed groove makes for easy living both for the teacher and the administrator, but it does not accomplish the results we should seek.

One way in which all of us fail as adminstrators, at least to some degree, is in assigning tasks only to those who are most competent. This accomplishes the immediate need for results with the minimum of effort, but it fails to develop younger men as they should be developed. Too many faculty committees are composed of willing, experienced, overloaded men. Too few are deliberately appointed with the purpose of developing latent capacities of those with more limited experience.

I once appointed a faculty committee composed entirely of instructors with the general job of "Efficiency and Economy." They were productive of much trouble both to me and to the older faculty, but their work was of much value to themselves. They attacked any problem they desired. With the enthusiasm and inexperience proper for their years they even attacked some of the "sacred cows" of the institution. Some of these they found lacking and some they found were still worthy of veneration. After studying their utility and finding them thus for themselves, all these young men were given a much better understanding of the whole matter of the policies of the institution and a much deeper appreciation of their own responsibilities.

In my earlier years as a college president, I faced the necessity of adding to the teaching staff. I drew up a careful set of specifications for the kind of men I wanted and set out to find them. After

a diligent search, I was much disappointed to find that there were no such men, so I was forced into the policy of selecting young men with partial qualifications and of interesting them in the acquiring of the necessary additional qualifications.

In my experience, I have found that the way to administer a faculty is not to "Catch 'em young, treat 'em rough, and tell 'em nothing," but to catch 'em young, treat 'em with consideration, and tell 'em everything they want to know. And, in addition, to provide every facility and encouragement for their growth and development, and for their understanding of the general problems of the institution. So treated, I have found that many a diffident man of fair ability, will expand and develop that enthusiasm and sympathetic understanding which are so necessary in the good teacher—without whom no faculty is worthy of the name.

In talking with one of the faculty at Rensselaer about what I should say on the subject of "Administering the Faculty," he remarked, "If you could explain how you wheedle this faculty into doing anything you want them to do it would be very illuminating." I wish he were right. But unfortunately, I have never yet been able to get a faculty to do everything I wanted. Whatever I have succeeded in getting them to do has been done because a study of the proposed changes has convinced them that they were the right things to do. Secure and permanent advance in the affairs of any institution, faculty, church, or political, can come only when those concerned are convinced of the rightness of the matter. The only intelligent way to reach a conviction of their rightness is by careful study. The business of the administrator of the faculty is to promote this study of all matters of importance. When men understand fully, they coöperate in intelligent teamwork to secure the results that we all seek.

THE ENGINEER AS A SERVANT OF SOCIETY *

By T. NORTH WHITEHEAD

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Our subject is "The Engineer as a Servant of Society." The title 'Engineer' is an elastic one but I am thinking principally of the highly trained university engineer. Modern society has been built up by the achievements of engineers and they have made possible life as we know it to-day; engineers have been indispensable to progressive societies from the time of the Roman Empire onwards, but their function has been changing quite radically during the last century. Economists and others tell us that we still behave as though we were living in an era of scarcity and they attribute many of our economic and political ills to this misunderstanding. The same remark applies to engineers. Until recently, the possibility of a worthwhile life for all depended on the development of mechanical invention and of better methods of production, but I wonder whether this is quite so true to-day. As engineers we like to feel that we have done our job of providing the goods, and that if only the economist and politician had done their job as well as we the world would be a happy place. 'Passing the buck' is a time-honored occupation, but I am going to suggest to you that the confusion of our present day society is at least as much the product of the engineers' technical achievements as of anything else.

A happy integrated society depends on something more than logic. It is built up of routines and customs, of friendships and obligations between people. Very little of anyone's activity is passed in thought-out argument of cause and effect. We behave as we do because we have always done so and because our parents did much the same before us. The intricate economic and social relations which exist between people, and between groups of people, is far beyond our logical grasp; for human society has built itself up over centuries and, like the insects, our actions are wiser than our understandings. This is one reason why it is such a serious thing to break down a society for, with the loss of custom and habit, human beings become almost unable to act together usefully. This is why revolutions are apt to be so terrible a disaster.

If we look at any society we shall find that it has evolved around

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its techniques, around its engineering skills, if you like; and the leaders of society are usually those men who organize and maintain its techniques. If we look at a primitive society we shall find its chieftains are those men who organize the hunting, who maintain the tribal customs, who are skilful in war and in such primitive commerce as the tribe may practice. If we move up the scale of civilization and think of societies which have depended on agriculture for their living, then we find that the leaders of society are those who own the land and organize the agricultural activities of the communities. This is equally true whether we think of the landed aristocracies of Europe or of the history of this continent.

It is no accident that Washington and Lincoln were both bred to the land. In our society to-day everyone is directly or indirectly dependent for his livelihood, his place of residence and for his enjoyment, on the men who have developed and organized our technical procedures. This places the responsibility for our society with all its merits and defects squarely on the shoulders of the engineer; for he is the man who has developed our technology and made possible not only our material world but also our social organization.

The engineer shares with other scientists the characteristic of being an inventor. He is constantly searching for new materials, new mechanisms, and better methods of production. And in this search he has been conspicuously successful. He has developed a technique of research which is absolutely unique in the history of the world; and in the future we may expect this technical advance to become quicker rather than slower. Now what does this mean for society? On the one hand, it means a possibility of a greater wealth expressed in terms of commodities, and on the other hand, there lies the danger of a progressive breakdown of those conservative habits of social relation and custom which alone can hold society together. This disintegration of the social process has already gone a long way in every industrial nation.

At the present moment we are all concerned with the recent rise of industrial unrest. This unrest is usually expressed in purely economic terms. The workers declare that what they need is higher wages, shorter hours or something of that sort. But people are notoriously unable to express their real needs. If that were not the fact, there would be no need for psychiatrists. So we shall do well to examine the real needs of these dissatisfied workers a little more closely.

Employee dissatisfactions have been a marked feature of our industrial civilization in every country, and we may take it as axiomatic that large bodies of men and women in several countries and over a number of generations are not expressing dissatisfaction from mere foolishness. They may be unable to diagnose the sources

of their dissatisfaction, but that there is a cause we may be very sure. At the present time, one thing is noticeable. The major unrest in this country is not occurring amongst the lowest paid workers, but, on the contrary, in those industries where pay and physical conditions of work are amongst the best that the world has ever seen. There are those who believe that this is merely an instance of the Machiavellian cleverness of the paid agitator. But happy people don't risk their jobs to follow political agitators into actions involving risk and hardship.

I suggest to you that industrial unrest is greatest in cities and communities of recent growth, where thousands of men and women have been drawn from all parts of the country and from foreign nations in pursuit of paid work made possible by the inventions of the engineer. These cities have sprung up like mushrooms. They have little or no historical background; stable customs and social behavior have had no chance to take root. Such cities represent the nearest thing possible to a socially unorganized mass of human individuals; consequently the social needs of human beings are being starved in such communities and life is correspondingly dreary and unsatisfying. Men and women are not being supported by their society and they are lonely and apprehensive. Their fate affects no one but themselves or their immediate dependents and they feel insecure. This, I repeat, we engineers must acknowledge as one of our many contributions to present day civilization. With one hand we give society an opportunity for material well-being and with the other hand we disrupt the society we serve.

Engineers, in the second half of the last century, were often referred to as the natural leaders of society. They pictured the benefits which would arise from a wealth of material goods. But for those of us now living, who have been trained as engineers, it has been a little disappointing to find that the administrator and politician has usually been the master, with the engineer as their paid assistant. We would not confess to this in public, but we may as well be honest amongst ourselves. The engineer has not quite taken that place in society to which his training and abilities would seem to entitle him.

The fact is, whilst the engineer has been decrying the administrator for a lack of scientific understanding, the engineer himself has not thought it necessary to investigate the nature of the society he has wished to lead. The engineer's conception of a good engineer has too frequently been formulated in terms of mechanical and economic efficiency; he has given little or no thought to social effectiveness when pursuing his work.

Our immediate problem is this: How can the engineer be so trained as to make his work contribute not only to the mechanical

progress but also to the stability of our society? It seems that he must not only be trained to be an efficient engineer, but he must also be given the understandings of a wise administrator. These two skills must be taught to some extent separately. The technical skill remains technical. For instance, in teaching the theory of thermodynamics in its application to steam there would be little sense in introducing social considerations. These latter must be considered as a subject in themselves. At the present time many engineering schools are attempting to give courses in one or more of the social sciences, but this movement has not been conspicuously successful. In the first place, it is doubtful whether the student is taught anything he really needs to know. Certainly the student does not think so, for he generally regards these courses as a waste of time.

A typical program is to teach the student a little elementary theory of economics and a sketchy course of the history of trade unions under the misleading title of "labor relations." The theory of economics is itself a highly abstract subject based on a very superficial understanding of human motives, whilst the course in labor relations represents an equally artificial account of a few negotiations, or trials of strength between groups of employees and their employers. These courses do not amount to a real study of human motives and human relations as they are found in an industrial society. For instance, the engineer is told nothing about the ways in which employees collaborate or relate with one another in their daily lives. No wonder the engineering student finds little connection between his interests as an engineer and his courses in the social sciences. Let us consider a more realistic approach.

A group of sociologists in the University of Chicago have published a number of studies of that city. They have investigated the types of peoples who live in the different districts and the occupations carried on there. They show conclusively that the city is not a mere haphazard collection of retail shops, factories, rich homes and poor homes, but that it has developed into a recognizable pattern. Engineering students should be acquainted with these studies.

Chicago is the home of many nationalities and it is shown that each nationality tends to live in a district of its own. It preserves a number of its old customs carried across the Atlantic from Europe. Such a compact foreign group is hard to assimilate into the larger society, but it is also found that the second generation of Americans coming from these foreign groups tend to disassociate themselves from their parents' customs before they have acquired those of the larger American society. The result is chaos and a rise of anti-social behavior. Again these sociologists' maps of Chi-

cago show that crime is most prevalent in those streets which serve as a boundary between two cultural groups. Along these streets, custom and social routines are weak and confused. In a number of ways the group of Chicago sociologists have explored the nature and extent of social integration in their cities, and their writings give some hint as to the importance of town-planning for human effectiveness. Naturally, every city has its own history and character—no two are quite alike. But every city is a living organism with its social processes, its development and its structure; and they are all composed of individuals and families with much the same basic needs and impulses.

The social structure of a city or a community concerns the engineer very closely. To mention only one instance, it is involved in the design of transport. Not only the transport of persons and commodities but also the transport of power and of information, as in the case of the telephone system. It would seem to be almost criminal to-day to design a transport system without a very serious consideration of its effect upon human relations within the district, and yet we give our engineering students little or no insight into this problem.

Let me give you another instance of the close relation between engineering techniques and the stability of human relations. Within the last few years the Western Electric Company at its Hawthorne Plant has made a series of elaborate studies into the manner in which its employees associate with one another during the course of their work. The results of these researches are highly significant. It was found that manual workers tend to come together in small groups even when this is not logically necessitated by the work itself. It was found, moreover, that the morale of the plant is very directly dependent upon the degree in which these small groups, of five to ten workers each, are being supported and encouraged by the layout of the plant and its machinery and by the supervisory organization.

When the arrangement of a large shop fails to recognize the tendency of human beings to associate in small groups—when the arrangement makes this difficult or impossible—then there results weak and dissatisfied groups of workers. A few researches, including those of the Western Electric Company, clearly indicate that the human integration of a plant begins at the bottom with small family-like groups of manual workers. Under wise leadership these groups enter into relations with one another, and so the morale of the plant builds up.

It is only recently that small primary groups of manual workers have been systematically studied in their daily life and far too little is known about them. Together with the family they repre-

sent the smallest cells or molecules from which society is built up. The parallel between a family and a small primary group of manual workers is really very close. In either case the members of the group tend to elaborate the things they do together, even when these activities are not apparently relevant to the work in hand. Moreover, many of the ways in which the members of a group collaborate are not explicitly known to them and, quite often, are outside the possibility of their deliberate control.

A small group of people having daily face-to-face relation has a life process of its own in some ways similar to the processes of a physiological organism, such as the human body. It resists its own disruption, and if its existence is threatened in any way a group will elaborate a whole series of activities designed to isolate it from the real or supposed danger. Very often the point of danger to the life of a group is conceived to be the firm's own management and particularly its technicians and engineers, who so habitually break down the life of their working groups in the quest for technological progress.

Restriction of output is to be understood far more as an alarm of workers whose social life is threatened than as the result of the economic reasons usually given. Only the other day I visited a large shop in which several hundred women were using power-driven sewing machines. The firm in question has a fine reputation for its labor relations. The pay is unusually good and rates are never cut. These women freely confessed that they were not earning as much as they comfortably could. Without any prompting from a union they were, in fact, restricting output. And the most noticeable feature of this shop, beside the high grade of help and the excellent physical conditions of work, was the fact that the sewing machines were arranged in rows along long benches in such a manner as positively to discourage the formation of small intimate groups of workers.

There is no mechanical reason why these machines, all driven from a central engine, should not have been arranged in small groups, but the engineer responsible for the design of the power shafting had made this a practical impossibility. He had no doubt arranged his shafting from the point of view of the simplest and most efficient mechanical layout. He had never been taught to think of the working society which was to use his machinery, and the result is that these machines are being run at about three-quarters of their possible capacity by an unsatisfied group of well-paid workers. Considerations such as these arise out of a real study of the day-to-day behavior and routine actions of people in their work. This is something quite different from a history of strikes and union agreements and is far more important for the engineer.

Perhaps I seem to be suggesting that we have the necessary knowledge, based on careful research, by which we can train young engineers to assist rather than to disrupt their society. Of course, I don't mean that. Literally billions of dollars have been spent in discovering the properties of steel and as yet a negligible amount of research has been spent on understanding the human factor. But although we have not a sufficient body of knowledge to give the engineer a clear-cut answer to his social problems, yet something has been done. There is the material at least to direct his attention to the presence of these problems, to give him a few useful hints as to how to think about them and observe for himself.

As engineers we know better than to design a structure without any regard for its material environment. No engineer in his senses would design the foundation of a bridge without first finding out whether the bridge would rest on clay or rock. We make a thorough investigation of the material circumstances in which our machinery and structures have to function. We design locomotives differently for hot and for cold climates, for wood and coal-burning districts. In consequence, we are thoroughly accustomed to research into the physical conditions which our commodities have to fit. Ultimately, however, the engineer does not work for the good of his material environment, but for the good of the human environment or society. And yet, surprisingly enough, the engineers are not accustomed to investigating the nature of their society before proceeding with their work. An engineer, who would be laughed out of court for designing a foundation without a knowledge of the ground, will cheerfully design a mechanism or structure with only a hearsay knowledge of the human beings who are to operate it or to benefit from it.

Until educational establishments regard sociological research as being of equal importance with research of a more strictly engineering nature, it is inevitable that the student will conclude that all he needs to know is a knowledge of applied science and mechanisms, and that their application to society can be safely left to the man who pays the bill. To-day wealthy institutions for the teaching of engineering habitually spend large sums on their workshops and laboratories, and then hire some junior professor of economics to look after a minor course in the social sciences. No wonder the student doubts its importance.

It is probable that the advent of really new discoveries such, for instance, as wireless thirty years ago, will remain incalculable and haphazard, for original ideas do not arise to order; but the development and improvement of existing processes and services have already been reduced to a fairly definite technique. The bulk of engineering activity does not consist in the production of

entirely new things but in the adaptation of existing mechanisms to particular situations, such, for instance, as the building of a given bridge or the development of a particular telephone service. It is in activities such as these that the engineer should be guided by a sociological approach in his work.

He should come to regard the happiness and stability of the society or community he serves as his main function, and his knowledge of technical engineering should be for him a means to this end. Too often to-day the engineer regards the mechanism itself as his ultimate concern and the public as a troublesome, but necessary adjunct in settling the bill. Only engineers who are placing the welfare of their society first can hope to be its leaders rather than its technicians. But this involves more than goodwill. A consideration for the welfare of society must be made effective by a serious and continuous research into the properties of the social process; its generalities and its individual differences. This type of research has barely started here and there; but if our industrial civilization is not to be destroyed by haphazard innovation, such investigations must be a prime concern of those responsible for the march of technical progress.

An exactly analogous situation has arisen in the university training of business administrators. These men share with engineers the practical control of the social process; and until lately it was considered sufficient to teach them the techniques required for the running of an enterprise, without paying any great regard to the repercussions of these on society at large. More recently it has become increasingly clear that the business man, together with the engineer, has come close to disrupting the society he was supposed to serve; moreover, it is evident that a business cannot hope to be more stable than the society of which it is only a part. Consequently business schools have been turning their attention to the wider training of their students as responsible members of society.

Specifically at the Harvard Business School, for some years research in the social aspects of business and industry has been undertaken, and teaching is based on this work. This teaching takes the form of discussions of actual business situations, or cases, which have been collected in the field by members of the school. Some of these cases have reference to problems of human collaboration entirely within particular firms, whilst others are concerned with the repercussions between the firm and the larger society. The point I am concerned to make is that worthwhile teaching in practical sociology, as in other subjects, must be based on adequate research. This is true, partly because a faculty cannot live on teaching alone, it requires the inspiration of a first-hand experi-

ence of research; and research into the social process is also required because so very little is known about this matter.

There is a third reason why sociological research will always be important to the engineer. This arises out of the difference between one human situation and the next. For just as the human relations of any two factories, or any two communities, have something in common, so do they also have their characteristic differences. A generalized knowledge of sociological fact will never be sufficient for the engineer. He will always have to supplement this with a particular study of the actual human situation for which he is designing his mechanism.

So, to sum up, I do not believe that our society can continue to tolerate highly trained engineers whose interest is exclusively centered in the details of their mechanisms. If the engineer is to be of help to his society, rather than a disruptive influence, he must be in essence a social leader who has at his command certain scientific skills. But social engineers will not arise until the great engineering schools recognize the collaborative activities of mankind as one of their major fields for research, and until those in charge of these schools regard money spent on this type of research as being of equal importance with that spent in exploring the nature of materials or in the development of mechanism.

Unless we can train engineers whose interest in the vital social processes is comparable to their technical interests, I fear that we engineers may be paving the way for a companion volume to Gibbons' "Decline and Fall of the Roman Empire."

EFFECTIVE TEACHING*

By A. A. POTTER

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Many addresses have been delivered before the Society for the Promotion of Engineering Education which have had a very beneficial effect upon the quality of instruction at engineering colleges. Of these, three papers have impressed me as worthy of special study. One by the late Professor W. T. Magruder, entitled "The Good Engineering Teacher," printed in the *Bulletin* of the S. P. E. E. of September, 1913, discussed the personality and training of the engineering teacher, and called particular attention to the importance of correct teaching methods. Professor Henry S. Jacoby in his talk "Some Details in Engineering Education" (*Bulletin* of S. P. E. E., Vol. VII, 1916), stressed the value and use of special aids in teaching, such as diagrams, mathematical equations, written reports, and devices intended to save the student's time during classroom periods, and concluded that "If students are to go out from college with high ideals of unselfish service, they need to come into association with teachers in college who embody the same ideals in their lives." A more recent paper on the "Importance of Teaching" by Professor Hardy Cross (JOURNAL OF ENGINEERING EDUCATION, January, 1937) called attention to the fact that "Teaching is an art—one of the finest arts—not a science. . . . As an art teaching is individual; it must adapt itself to him that gives and to him that takes, as well as to the subject taught." Of recent addresses on teaching, delivered outside of our profession, the one by E. P. Lyon, Dean of the Medical School of the University of Minnesota (*Sigma Xi Quarterly*, 1936), entitled "Teaching and Research," should prove of interest to all teachers in higher educational institutions. His views of the New Atlantis University merit careful consideration, but some would take exception to his advice that persons of good morals, willingness and courtesy, who can neither teach nor investigate, should be appointed as deans.

In this talk I shall devote major attention to the factors, other than techniques, which contribute to the effectiveness of a teacher. Engineering colleges have always looked upon teaching as their main function and the quality of instruction as a major responsi-

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bility. In order to benefit by the opinions of the learners a request was sent to 1,390 graduates from Purdue University of the classes of 1934 and 1935 to outline their judgments of the "characteristics of a good teacher." 1,158 replies were received and these indicate that the good teacher should have to his credit the following attributes:

1. Knowledge of the subject he teaches.
2. Effective presentation. The replies under this heading included such statements as the ability to hold the student's interest, proper coordination of the theoretical and practical, power of expression, enthusiasm, human approach, emphasis of important points, persistence with the slow student and thoroughness.
3. Desirable traits. In this category were included strong character, superior ability, good attitude, balanced philosophy of life, alertness, broadmindedness, courtesy, friendliness, diplomacy, energy, proper ethics, fairmindedness, gentleness, industriousness, kindness, neatness, sense of humor, sincerity, thoroughness, tact and broad tolerance.
4. High culture and superior general education.
5. Effectiveness in class management.
6. Practical experience.

If specifications were to be written for an effective teacher they should include the following:

The teacher must first of all be a person of character. A person who has low ethical standards has no place in the American educational system. A teacher who condones dishonesty, deceit, and trickery, or who evades the laws of the land, even in spirit, is neither a good teacher nor a good citizen. A teacher who lacks sincerity or who bluffs or exaggerates is a detriment to any educational institution. A drunkard, a libertine or a liar must not be tolerated in the teaching profession where the well-being of young people is involved. A teacher who is absolutely moral, clean, just, dependable, punctual, accurate, mentally honest, industrious, conscientious, and courageous is the type of person who is in a position to instill sound character and an appreciation of right living in his students.

I am sometimes puzzled by the code of ethics of certain college teachers. In most professions the practitioner guards most jealously the reputation of others in his specialty. University teachers have been found to criticise their own colleagues behind their backs and even to run down the competence of teachers before their students.

Unbounded enthusiasm is a major characteristic of the good teacher. His enthusiasm radiates to those about him in the sparkle

of his eye and the vibrancy of his voice; students are fascinated by his general animation and by his interest in the subject he teaches. When a teacher loses his enthusiasm and his ability to inspire his students with an eagerness to learn and an interest in the search of knowledge he should retire from teaching. Teachers will do well to study the methods of the successful coaches of our colleges, and they will realize that character, personality, enthusiasm and superior teaching technique on the part of such coaches are largely responsible for the victories of athletic teams.

Sarcasm, conceit, snobbishness, selfishness, profanity, antagonism, or intolerance are traits which characterize the poor teacher. A person who has any such traits or is careless about his dress or appearance has no place on a university faculty.

No teacher should be tolerated if he is merely a hireling and a time-server; he must be bubbling over with enthusiasm for the subject he teaches if he is to inspire his students to become scholars and thinkers. Neither is there a place for a teacher who is impatient, who lacks self-control, who is non-coöperative or disloyal. A teacher who cannot be loyal to the institution he serves and to its policies should seek opportunities elsewhere. No self-respecting individual accepts compensation from an organization to which he cannot devote himself loyally and unselfishly.

The master teacher is always agreeable, courteous, considerate, accommodating, kind, patient, diplomatic, optimistic, tactful, and inspiring. He commands the respect of his students and is in a position to develop in them habits of courage, straight thinking, sound reasoning, industry, and a definite interest in the intellectual and the æsthetic. It was Goethe who said "We learn only from those we love."

The good teacher is a clear thinker and bases his statements upon facts. He thinks in terms of principles and is not merely an imitator of others. He has the ability to analyze and synthesize the facts involved in any problem and arrives at solutions objectively without prejudice. He has cultivated in himself intellectual curiosity and habits of study, and is able to instill these qualities in his students.

The effective teacher is well versed in his mother tongue and has the ability to express himself clearly and correctly. He can talk audibly enough to be easily heard and his enunciation is such as to be easily understood. He is constantly enlarging his vocabulary through his reading and encourages his students to do likewise.

The good teacher is a master of the subject he teaches and is able to draw out from his students the best that is in them. One whose education has been limited only to the subjects that he is trying to impart is unfit to occupy a post at an institution of higher

learning; the teacher must broaden his vision through advanced study and experience before he attempts to teach, particularly at the institution from which he received his bachelor's degree. Graduate study, engineering experience, reading, travel, and a keen interest in young people and in their problems are essential prerequisites. A person who has never worked for pay in a shop, plant or on a construction job, and who has never rubbed elbows with workers, unskilled as well as skilled, lacks essential experience for engineering teaching. The judgment of values which the engineer must possess can best be acquired through experience with men, things and ideas. At the same time it must be remembered that knowing only the facts to be taught does not necessarily make a good teacher. Those in executive positions in colleges and universities have had sad experiences when they added to their staffs engineers of wide practical experience, who knew nothing about teaching, who did not realize that teaching is an art and who merely imparted knowledge of a very specialized type.

To be effective one must teach people and not subjects. The teacher must know and must have a sympathetic interest in each student. He must base his instruction upon the preparation and aptitude of each of his students and not upon a theoretical median.

The good teacher aids his students in learning how to study, how to plan their work and how to reduce lost motion. He develops the students' proper mental attitude toward their studies and surroundings. He is constantly pointing out applications of the problems under consideration. He is aiding his students to differentiate between facts and opinions, and impresses upon them the necessity of developing an analytical attitude and a social consciousness.

Research in an educational institution should have as its main objective the improvement of its principal product, the student. Research, either in methods of teaching or in the specialty of the teacher, is definitely helpful to the teacher in keeping up to date and in increasing the inspirational value of his teaching. In fact every good teacher is necessarily a scholar. Professor Hardy Cross states that "a teacher, who is constantly trying to master his field, almost invariably produces research, books, articles, addresses. He wants to know not to be a research man but in order that he may teach well." While I am the last person to recommend that the advancement of teachers be based solely upon their contributions through research, the fact remains that most teachers who carry on no research, who do no writing and who are unknown even in their own field have little inspirational value and are usually found to lack initiative or ability to improve themselves or others. Bridge, golf, household tinkering and poor planning of one's time account for the relatively insignificant productivity of the majority of col-

lege teachers. Teachers who are receiving little advancement will find upon careful analysis that they through their own laziness are definitely in a rut; a rut, it should be remembered, differs from a grave only in dimensions and outlets.

In the report of the Investigation of Engineering Education, conducted by the S. P. E. E. more than ten years ago, the conclusions of the Study of Engineering Teaching Personnel were "that the real problem before us is that of securing the right type of teachers for engineering faculties. On it hangs the satisfactory solution of our most serious educational problems. It has been well said that engineering education will never be better than its teachers." There is always a scarcity of inspiring teachers who are also known to be masters in their own fields. However, the best colleges are not interested in teachers who merely meet their classes, who show no personal or sympathetic interest in their students, who contribute nothing to the advancement of their profession, and who are unwilling to prepare themselves by constant study to be recognized as experts and scholars.

A college or university is the top story of the educational structure; it is made up of a number of persons in one body, something like the guild of old, but whose main interests are concerned with creating, imparting, preserving and acquiring knowledge. In the true university all are learners; teachers and pupils alike are scholars. There should be very little gap between the student and the teacher and absolutely no bridge between teachers of different ranks. Academic titles, such as instructor, professor, dean and president are intended merely to be rewards for scholarship and effectiveness of individuals as teachers or creators of knowledge. Such titles, however, are not intended to involve military line authority. Assistant, instructor, professor, dean and president are all colleagues who should coöperate in the interest of the learner and for the advancement of scholarship.

Teaching is an idealistic profession, like music or painting. The teacher, like the artist, does his best if he works in an environment which is pleasant and free from organization worries. The higher the rank the teacher holds, the greater is his responsibility for true scholarship and for the guidance of others. The young instructor teaches routine and elementary subjects. As he gains mastery of his specialty and proves himself able to inspire his students and to create new knowledge or to develop better teaching methods through his own scholarship, he is advanced in rank and responsibility. The title professor indicates the highest honor the university can award to any teacher; it stamps him as an inspiring guide of his students and as an authority in his own special field.

The head of the department is a person who, in addition to his standing as a teacher and authority in his specialty, is expected to have the ability to inspire his younger associates to greater endeavor. A head of department who treats his colleagues as his subordinates or who feels that he has to bear down upon the teachers he is expected to develop, stimulate and encourage is more fitted to be a boss of a construction gang than a head professor. A dean, like a department head, should be a teacher and investigator who continues his scholarly endeavors and is not a mere administrative officer. He is expected to interpret the needs of his staff to the president and trustees, and must be the guardian of the standards and prestige of the school entrusted to his care. His major task, however, is that of a catalyst, who stimulates, inspires and encourages his colleagues and students in their scholarly endeavors.

Finally it must be remembered that the compensation of the effective teacher is not represented by his pay check; much of it comes in the reward of work well done in an atmosphere which is conducive to high ethical standards and productive scholarship. The master teacher loves his work and derives satisfaction from the accomplishments of his former students. Furthermore, those of us who are on the staffs of higher educational institutions enjoy a social status which money cannot buy, and our families have cultural and educational advantages which those in business or in other professions can purchase only at a high price, if at all. A fair appraisal of the life and work of the college teacher leads to the conclusion that he is most fortunate in the rewards and satisfactions of life which his calling affords him.

LOOKING AHEAD IN ENGINEERING EDUCATION*

By FRANK L. EIDMANN

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Engineering education is in a state of continuous and gradual transition. The changes that are going on in the engineering curricula, in the methods of instruction and in the colleges themselves are the results of many factors. These fundamental influencing factors are the economic, social and political changes that are constantly going on; and developments in science and engineering. Incidental to these broad factors are the great increase in the number of engineering colleges throughout the country; the large number of engineering graduates now in industry; the rapid growth in the enrollment of engineering colleges; the constant demand for the addition of courses to the curriculum; changes in methods of instruction; and the accrediting of engineering colleges. Even the geographical distribution of the students in the older engineering colleges has greatly changed. In the past when there from all parts of the country.

Now, however, there are so many excellent engineering colleges throughout the entire country that a student does not have to go far from his home to attend a suitable college. In consequence most engineering colleges have become comparatively local institutions, drawing most of their students from the territory immediately surrounding the college. This change naturally presents many problems to the colleges.

It is my purpose, in this paper, to draw attention to some of the changes and developments that appear to be on the way in engineering education, judging from trends; as well as to point out some developments that I personally believe are needed. These trends should be considered from five viewpoints: (1) the college; (2) the curriculum; (3) the student; (4) the instructor; and (5) the employer of engineers.

The College

Looking ahead from the viewpoint of the colleges themselves, there appears to be much room for coöperation between the colleges, as well as between the colleges and industry and the professional engineering societies.

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(1) It seems to me that there is need for an arrangement whereby a student may attend any of the liberal arts colleges for two or three years, then transferring to an engineering school to obtain his bachelor of engineering degree in two years. The degree may be given by either institution, or jointly. I realize the difficulties in making such arrangements, but they are not insurmountable.

(2) Similarly there should be an arrangement between engineering colleges whereby a student of one college may transfer credit for a reasonable number of courses taken in other accredited engineering colleges. This should especially be possible for specialized courses (perhaps as electives) and for work leading to advanced degrees. I know of an instance of this kind where a candidate for the doctorate in the geology department of one university did his entire thesis in a second university because of an outstanding professor who specialized in the line of the student's interest. I inquired at both universities as to the success of the plan and I learned that it worked out very satisfactorily.

(3) Where engineering colleges are near each other as in a metropolitan district I should like to see this idea extended so that some engineering colleges will specialize in certain lines and will develop outstanding courses, instead of each college attempting to cover fully all fields. Such lines might be diesel engines, heat transfer, electronics, fluid mechanics, process machinery and others. Arrangement can be made for individual students, and possibly entire classes, from other colleges to take these courses for credit. This plan will save duplication of expensive equipment and will provide more expert instruction.

(4) There are other ways in which the duplication of expensive equipment and facilities of specialized nature can be eliminated. For example: Summer schedules can be arranged so that two or more colleges can in some cases use the same surveying camp. Similarly, a well-equipped machine shop can serve for the instruction in shop courses of more than one college. These are typical of many examples.

Plans for the coöperation of colleges with Industry and with the professional engineering societies will be discussed later in this paper.

The Curriculum

In comparing the engineering curriculum of today with that of the past we find the following trends:

(1) A change from the practical and descriptive course to one which is more analytical, mathematical and scientific in treatment.

(2) Combining of related subjects into a single course. Examples: Combining of instruction in strength of materials and the selection of engineering materials; machine design with kinematics; engineering drawing with descriptive geometry.

(3) Increased emphasis on humanistic and cultural subjects.

(4) A growing emphasis on *fundamentals* of science and engineering.

(5) An increase in the number of subjects to be studied.

(6) A growing trend to allow for student selection of elective subjects and technical options. In some colleges the student may major in one of several divisions of specialization in his branch of engineering.

I recently contacted by plant visit or mail a large number of manufacturing plants in many lines of industry. Among my questions was "Do you prefer that your young engineers have taken specialized courses or that they simply have the fundamentals of science and engineering?" In nearly all cases the preference was for sound training in the fundamentals.

I also asked "Do you prefer men who have taken a year or two of postgraduate work?" A great majority expressed themselves strongly in favor of the graduate of the four year course in preference to the postgraduate in spite of the fact that many of the replies came from firms whose work is of highly technical nature. Some firms stated that they occasionally take on a postgraduate when they have some highly specialized work but that for other work they prefer not to have the engineer who had taken graduate work before his employment.

It was interesting to note in these replies that those firms which have hired graduates of coöperative courses in engineering are greatly impressed by the satisfactory performance and attitude of these men.

Many interesting answers were received to the question "In what way do you believe that four-year courses in mechanical engineering may be improved?" A number suggested the elimination of specialized courses and concentrating in fundamentals. Quite a few want greater emphasis on the fundamentals of business administration and instruction that tends to make the engineer "cost-minded." Some stated that they are becoming increasingly impressed with the value of a "General" engineering course. A number made the comment that our engineering colleges seem to take for granted that all engineers are to be research men.

These comments from industrial firms regarding matters of the curriculum are not necessarily to be interpreted as trends, but I believe that they are significant and warrant further investigation and consideration.

From the Viewpoint of the Student

(1) All that has been stated in the foregoing regarding the curriculum has, of course, a direct bearing on the student. In commenting on the future from the viewpoint of the student I should like to add, however, my prediction that more use will be made in the future, of engineering aptitude tests both in the selection of students for engineering colleges and in the selection of young graduates for employment.

(2) Many employers of young engineering graduates show a strong preference for men who have spent their summers in industry. They point out that these men have a much better attitude toward their work; are much more likely to know that they wish to make engineering their life career; and it takes considerably less time to train them. Some engineering schools recognize this and require their students to work in industry during their summers and to write a report.

(3) There is a need for Traveling Fellowships for engineering students—for travel in this country as well as in foreign countries. I know of only one such Fellowship whereas there are many available annually in other fields of study. Only last week one of our host institutions announced foreign travel fellowships to the value of $18,000 but none went to students of engineering.

The Faculty

From the viewpoint of the teaching staff there are a number of progressive steps that are either being talked of or which have been instituted by one or more colleges.

(1) One of the most important is a suggested course for young engineering instructors. There is a growing realization that our present methods of starting out young engineering graduates as instructors are unsatisfactory. I believe the time is right for this Society to take the leadership and organize a course to be presented for young engineering instructors. A three-week summer course would undoubtedly prove to be a valuable contribution to engineering education.

(2) It is hoped that more engineering colleges will be able to place travel funds at the disposal of the younger members of their faculties for travel and investigations relating to their teaching. A friend of one engineering college donates $1,000 annually for this purpose. The entire amount is allotted to one member of the faculty each year and the results have warranted the expenditure.

(3) Another valuable contribution to the teaching of engineering is that of the specialist in an engineering subject who presents his course at several colleges. This is already being done, and so far as I know is proving a success. I look for this idea to spread.

The Graduate

(1) One of the most neglected fields and yet one offering great possibilities in engineering education is that of instruction of an advanced or specialized nature for engineering graduates—especially for those who are employed. Unfortunately there are few engineering colleges that have organized educational programs for their graduates or for graduates of other colleges. Among the ways in which the colleges may contribute to the advancement of engineering education for graduates are:

(*a*) Graduate courses leading to advanced degrees.
(*b*) Evening service courses.
(*c*) Postgraduate conferences and discussion groups.
(*d*) Coöperation with Industry in the layout of training courses for engineering graduates.

Graduate courses leading to advanced degrees in engineering are provided by many colleges, but can be attended by comparatively few students, and are needed mostly by those who expect to enter teaching or research fields.

The evening courses offer great possibilities and there is a need for them especially in colleges located in the cities. Graduates need these specialized courses in their work and in very few cases is there any desire or need for credit towards an advanced degree.

Several colleges have instituted postgraduate conferences or discussion groups on specialized subjects either evenings or for short periods during the summer. These conferences are proving of interest and value.

My investigations indicate that a very large percentage of engineering graduates flounder for a few years (and sometimes permanently) after entering industry. They are simply lost, and are badly in need of guidance. Few firms are properly organized to give this guidance even if they have a so-called training program—which is usually a plan of shifting the graduate from one department to another and letting him pick up what information he can. Nine out of every ten young engineers are very much in need of guidance at this stage of their career and I am of the firm conviction that one of the best services that the engineering colleges can render their graduates is to coöperate with industry to guide, orient and train these young men for a year or two following their graduation.

Some of the professional engineering societies are organizing educational programs for their members. Courses of study and series of lectures on special subjects are presented. I look for practically all of the professional engineering societies to become active in this splendid contribution to the advancement of engineer-

ing education, and I look forward to the engineering colleges to cooperate in the work and wherever possible have their students take these courses—which are presented by leading practicing specialists in their respective fields.

The Employer of Engineers

With the increasing number of engineering graduates who are today filling executive positions it is natural that our engineering curricula and our methods of teaching are being more critically evaluated by industry. Employers of engineers are intensely interested, and are giving considerable thought to the education of engineering students and they have some definite ideas as to the education which the young graduate needs for work in industry.

Knowing the kind of reception that usually confronts questionnaires I was agreeably surprised at the generous response to the one that I recently mailed out. An unusually high percentage (close to 100 per cent) of replies has been received.

The direct answers to the questions were in nearly every case accompanied by a supplementary letter of valuable comments. These letters were in most instances from two to four pages of single spacing signed by chairmen of boards, presidents and works managers, and all indicated great interest in the training of engineers. Whether educators do or do not agree with comments from industry is immaterial. I believe that colleges should have organized plans for keeping in touch with industry and that complaints and suggestions should be given serious attention as a basis for the improvement of engineering training.

Many firms have excellent training programs which include advanced study of specialized nature, and many additional firms would be glad to institute such programs if the colleges offered their coöperation.

In closing I wish to state that I have mentioned only a few of the many trends and that from whatever viewpoint we look at engineering education there are tremendous opportunities for progress and development.

THE MISSING LINK BETWEEN THE ENGINEER AND THE MATHEMATICIAN*

By J. L. SYNGE

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We are all too apt to forget that science is made by man, and that man is a strange erratic being, not governed by fixed laws, always wanting to do the things he ought not to do and leaving undone the things which he ought to do. If a voyager from Mars were to alight momentarily on the earth and fly off with a bundle of scientific periodicals, he would form from their perusal a very strange view of mankind and of science. For no scientific writer reveals *why* he has gone to so much labour in doing the work which he has done. The mathematician seems to construct theorem after theorem for no apparent reason. The engineer designs machines for the comfort of his lazy fellow-man, who has to resort to golf to get the necessary exercise of which the engineer has deprived him. The whole business of science may appear so pointless that we may well pull ourselves up sharply, and ask why we are doing all this. Why do so many men, engineers and mathematicians, dedicate their lives so gladly to incessant toil?

It has not always been so, and it seems unlikely that it will always be so. Even in our life-times changes have occurred, and it is well to take stock of the present situation and appraise it, in order that we may move forward into the future with some knowledge of our destination.

An engineer who succeeded in cutting in half the cost of power-production would regard himself as a great man, and would be highly honoured. But listen to what the greatest biographer of all time wrote of the attitude towards his inventions of one who, considering the age in which he lived, may be considered as one of the greatest engineers of all time. Certainly, had he never lived, modern engineering would not have been possible, for he established on a firm basis the principles of mechanical advantage, the principles of hydrostatics and the foundations of the integral calculus. This is what Plutarch says of the attitude of Archimedes towards his mechanical inventions: "He possessed so high a spirit, so profound a soul, and such treasures of scientific knowledge, that though these

* Address before the 45th annual meeting, S. P. E. E., Cambridge, June 28–July 2, 1937.

inventions had gained for him the renown of more than human sagacity, he yet would not deign to leave behind him any written work on such subjects, but, regarding as ignoble and sordid the business of mechanics and every sort of art which is directed to use and profit, he placed his whole ambition in those speculations in whose beauty and subtlety there is no admixture of the common needs of life."

Those words are blasphemy to an engineer. But they are the creed of the modern mathematician. And that is why I have ventured to address you on the missing link between the engineer and the mathematician.

It is usual nowadays to assume that wisdom was born with us, and that we are entitled to treat the ancients with condescending patronage; therefore it may seem inapposite to mention Archimedes as a living interest to engineers in Cambridge in 1937 A.D. But if you will jump 2100 years from Archimedes into the nineteenth century, you will find the same sort of spirit showing in a man to whom we are more immediately indebted—Michael Faraday. He patented none of his inventions, and yet he is the founder of electrical engineering.

It might appear safe to extrapolate into the future and assume that there will continue to be born from time to time men who will make discoveries revolutionising engineering, but caring nothing for the exploitation of those discoveries. But when we look a little more closely into the historical precedents, we see that Archimedes and Faraday, to mention these two, were not trees sprouting alone from barren rock. They both grew in a soil suitable to their growth. There were around them lesser shoots, trying to grow to the same height but not succeeding.

In the nineteenth century the soil was particularly rich. Although Faraday might stand aloof as a pure scientist, there were others who combined scientific gifts of the first order with the capacity and desire to exploit. Outstanding among these was Kelvin. In fact, if the words of Plutarch regarding Archimedes sound strangely to us, it is because we are still, to a certain extent, dominated by the strong personality of Kelvin. As long as Kelvin lived, the link between the engineer and the mathematician was not missing: Kelvin himself was a powerful link. And because Kelvin was for so long a dominating influence in British science, we find still today in Great Britain the link between the engineer and the mathematician stronger than anywhere else in the world.

But here in North America, in spite of the laudable efforts of this Society and of individuals, the link appears to be very weak—so much so that I have ventured to refer to it as missing. But I would like to say in explanation that I do so in no spirit of disre-

spect to those who do form the link: my purpose is to stress the importance of their work, not to deprecate it.

Why is the link so weak here? In a country of great undeveloped resources and a rapidly increasing population demanding transportation and the amenities of life, it was natural that professional engineering should develop to great strength. But pure science is a slower growth. Mathematics in North America was not important during the nineteenth century. In the twentieth century, under the influence of some outstanding mathematicians, mathematics has developed to such an extent that the United States now stands in the first rank. But an examination of modern mathematics here will show that it has grown in certain directions. It is a tree with some branches of great strength, others very weak. Unfortunately it is those branches which should stretch out towards engineering that are most poorly developed. In fact, mathematics in North America means rather definitely pure mathematics. As a fairly regular attendant at the meetings of the American Mathematical Society, I would say that this tendency is increasing. The younger men tend more and more to that side of mathematics in which "there is no admixture of the common needs of life."

Now I do not quarrel with the attitude of Archimedes. Plutarch has summed up admirably the view of the pure scientist, and you will find in the writings of Faraday endorsement of that view. I do not believe that most dollars are saved by those who set out to save dollars. Great discoveries spring from a disinterested mind. But I do hold most strongly that there is room, and much room, for scientists who will fill the growing gap between the engineer and the mathematician.

The difference between the electrical engineer and the pure mathematician does not lie merely in the fact that the engineer knows all about dynamos and transmission lines while the mathematician knows all about groups and differential equations. There is a much more subtle and important difference: their minds move along quite different lines. The engineer wants results; the mathematician wants proofs. They have different ideas in intellectual architecture. The engineer wants something that will keep out the wind and rain: he collects all the rough empirical lumber he can lay hands on, nails it roughly together, and so builds his house: it stands up. If he tries to add a second story, it will probably collapse. On the other hand the pure mathematician spends his whole life carefully laying one foundation stone: it is laid with the greatest beauty and precision, but it does not keep out the wind and rain.

Can we not effect a compromise between these two extremes? Can we not construct our building somewhat more carefully, but without such a meticulous regard to detail? I believe we can.

And if you will look back over the history of mathematics, in the wide sense, during the past three centuries, you will find that a great deal of the building—and the most beautiful and inspiring building—has been just of that type. Indeed, the pure mathematician has been occupying himself to a considerable extent recently in placing gradually these buildings on firmer foundations. But, as in the case of many architectural reconstructions, the simple beauty of the original building has often suffered in the process.

It is at least encouraging to find that the engineer and the mathematician have this much in common—they are both builders. And here is perhaps the answer to the riddle I propounded earlier—why are we doing all this? The answer is simply that, like the beaver, man is born to build, although he displays a disconcerting originality in the material he employs.

I have, in my experience as a teacher and in my own studies, given much thought to the processes of learning and discovery. It seems to me that two essentials are involved:

(1) a goal towards which the mind is attracted:
(2) a guide to indicate the next step.

In fact, the intellectual process may be compared to a journey by road from Boston to New York. First, the traveller must have an objective and a desire to reach it. Secondly, he must have a map or sign-posts in order that he may find his way.

Let me illustrate what I mean by an example in learning. A student is interested, let us say, in the problem of the simple pendulum. He has a goal before him; he wants to understand the behaviour of the pendulum, to find its periodic time and the way in which that periodic time depends on amplitude. Obviously, the goal alone does not suffice. He does not know what steps to take in order to reach the desired knowledge, so he relies on a text-book or teacher for guide. The goal and the guide are both essential. It is useless for the student to sit and contemplate the problem from afar without any means of approaching it. It is equally useless for him to be led by his teacher through a number of steps of reasoning without knowing what he is heading for.

But even when the student has been led to his goal, the process of learning is not complete. Have you ever noticed that you learn nothing of the geography of a strange city when you are led through it by a friend? Return by yourself, and you will be all mixed up. You must learn for yourself. You must construct your own mental map. And that is why the results of examinations are often so disappointing. Students think that because you have led them along the path, they will be able to find their own way: only those who have constructed their own maps succeed.

Now let us pass from the process of learning to the process of discovery. What of the goal and the guide in that case? The goal is often vague and hazy. Perhaps when you come up to it, you find it is not there. In fact, one of the arts of discovery lies in appreciating intuitively beforehand whether there is really a goal or not.

As for a guide, there is now no text-book or teacher. You have come to the edge of the map, and thereafter have to follow your own nose. But you do not go blindly—else you would get nowhere. Here is where experience counts. You have not been along this particular path before, but you have been along many others, and the tricks which availed you before may do so again. You try them. Man's originality is grossly overrated: he proceeds chiefly by modifications of previous experience. A man's capacity for discovery depends on the passion of his desire to reach a goal and on his imaginative skill in utilising, by modification, his previous experience.

That brings me to a point in this address where I can be more definite. We are interested here, I may assume, primarily in the development of young men capable of making fundamental discoveries of engineering importance. And when I say "fundamental," I mean at the same time "mathematical," because we are not interested at the moment in discoveries which are the immediate results of experiment.

Such a man is rare: let us admit at once that this is no case to which mass-production is applicable. But, granted an individual, highly endowed with the necessary natural gifts, what shall we do in order that he may utilise them to advantage?

Mathematicians, especially great ones, mature young. The preparation for discovery should start at a very early age. Limitations of time prevent me from dealing with what is really a question of fundamental importance—the public- and high-school education of those destined to be great mathematical scientists—, but I shall revert briefly to the question of early training in my closing remarks.

Let us then face the actual situation, in which a student enters a university or institute of technology with such mathematical equipment as the state in its wisdom has seen fit to provide. His mathematical experience at that stage is extremely meagre. Now I want to make it quite clear that I am not recommending mathematics in large doses for all engineers: I think that this business of selling mathematics to the million is foolish and actually stultifying. There are too few good students of mathematics and too many bad ones already. So my remarks are intended to apply only to those students who are definitely well equipped with the natural gifts necessary to enable them to be mathematical engineers, or, if you like, engineer-mathematicians.

The question of importance is this: given four years to be followed by a couple of years of graduate study, with what stock of mathematical and other experience should such a young man be supplied? The first and obvious desideratum is that he should be treated as one of a small selected group, and not placed with the general herd, because his diet must be so different. I have not the necessary technical knowledge of engineering to outline such a course on the professional side. In fact, it would have to be done by one who is himself a link between engineering and mathematics. But I do feel some confidence in dealing with a phase of experience lying next to, but just outside, the technical domain. To that phase of experience the name "applied mathematics" is given. The name is rather deceptive, and its literal interpretation may lead to a lot of harm in the training of the mathematical engineer.

One can take a delightfully simple, but historically false, view of the relations between the pure mathematician, the applied mathematician and the engineer, and I fear that it is a view rather widely held. According to this view, the pure mathematician follows his nose into the unknown: he evolves methods and theorems which he throws back over his shoulder to the applied mathematician, who follows him: the applied mathematician works out the applications, and in turn throws them over his shoulder to the engineer, who comes last. I believe that view to be true only in a very limited degree. Rather I would say that first come the engineer and the physicist, digging out crude empirical methods, then comes the applied mathematician, reducing these crudities to order and generalising them, and finally the pure mathematician refines these results and treats them so comprehensively and compactly that the mountain of the engineer becomes the mole-hill of the mathematician. That this process does not operate better today is due to the fact that there are so few mathematicians whose ranges of interest overlap with those of engineers. The pure mathematician is, as a rule, nauseated by the crudity of the engineer's approach.

As an undergraduate in Dublin I learned pure and applied mathematics side by side. Quite early I became initiated into that fascinating imaginary world where there are particles of no size, perfectly rigid bodies, perfectly incompressible fluids and perfectly spherical conductors. I never found any difficulty in entering that world: I liked it, and I like it still, better than this actual confusing world in which we live.

But every one does not take so kindly to this fantastic ideal world. Some find great difficulty in entering into the spirit of the game, and I would say that few students feel at home without a fairly thorough experience of it, ranging over at least two years. Pure mathematicians enter easily enough into this domain, but they

may cause a lot of trouble by paying too much attention to details which appear important to them, but are not important physically. Those, from Newton down, who have known the proper attitude to adopt, have handled this model universe with consummate skill. Knowing that man lives only for three score years and ten, they have wisely refrained from allowing a mathematical overgrowth to stultify the model by complicating it too much. Those acquainted with the theory of relativity will know what I mean when I contrast the admirable and lucid constraint of Einstein and Minkowski with the embarrassing growth of mathematics which the last twenty years have produced around relativity, much of it apparently not physically germane.

So what I would place at the fore-front of the education of a man destined to be an engineer-mathematician is a thorough initiation into this fantastic ideal world of the applied mathematician. Since mechanics is not taught as a mathematical subject in the high-schools, the student has not had any opportunity of getting acquainted with these abstract ideas before he becomes an undergraduate. Side by side with this should go a training in basic pure mathematics, but care should be taken not to let this go too far beyond the realisation of its applicability. In fact, our engineer-mathematician has to keep in mind, and correlate with facility, three different universes. First, the actual physical universe: if he loses sight of that, he is no engineer. Secondly, the ideal universe, which may be regarded as the actual universe, simplified so drastically as to be amenable to mathematical treatment. Lastly, the universe of the pure mathematician, in which he finds particular methods given such an aspect of generality that he is able to systematise his knowledge and reduce its bulk to a minimum.

As for those particular subjects dealing with the ideal universe in which he should be well trained, I would without hesitation place mechanics first. The interest of the pure mathematician in a mechanical problem starts as soon as the differential equations are written down. My experience as teacher and examiner leads me to the conclusion that most students find it harder to obtain equations of motion than to solve them. That is because they are much more at home in the domain of the pure mathematician than in the ideal world of which I have spoken. In fact, the reduction of a physical problem to mathematical form is a bridge that many cannot cross—only those who feel at home in the ideal universe, which has been evolved by centuries of thought to enable scientists to make that reduction.

With mechanics I would associate electrostatics, hydrodynamics and elasticity, both for their own direct importance and because they give concrete physical pictures of mathematical methods of

general applicability. A man with the mind of an engineer rightly revolts from an argument which loses all contact with physical reality. Every step in an argument should, as far as possible, have its physical meaning. And I insist that the physical picture should be first created and the mathematical method evolved naturally to solve it. That is the true historical order, and the one that has the most convincing appeal.

Finally our engineer-mathematician will, especially if he is to concentrate on electrical engineering, require a sound training in electromagnetism. Here he will find all his previous work of the greatest value. The foundations of electromagnetic theory were laid by men whose minds were soaked in the older subjects which I have mentioned. It is much easier to study field theory if one is already familiar with basic ideas in hydrodynamics and elasticity. Some electromagnetic concepts, such as flux and stress, are then easy to grasp, because they are modifications of ideas already familiar, and the student can concentrate his attention on the really difficult novelties, such as the question as to how far the Poynting vector corresponds in reality to a flux of energy.

The student of electromagnetism should realise that it is a young subject in comparison with the others I have mentioned. It has a lot of raw ends, not properly finished off. Einstein is reported to have said that it should be possible to write the essential parts of a good theory on a single sheet of paper, and he proceeded to do it for the general theory of relativity. We all know that the fundamental facts of Newtonian mechanics can be written on a post-card, and we might throw in Lagrange's equations for good measure. So also might the fundamentals of electrostatics, hydrodynamics or elasticity be briefly put. But I would be very grateful to anyone who will be so kind as to give me a similar précis of electromagnetism—including cases of moving circuits with sliding contacts. I believe that there is scope for work—important work—in cleaning up the untidiness that hangs around electromagnetism. I cannot see that it is likely to be done by any of our pure mathematicians, because they have not the necessary engineering knowledge and also because pure mathematicians are so keen on exactitude that they may easily fail to realise just how much and how little attention to detail is requisite for the successful formulation of a theory, which is an art in itself. Nor can I see that the ordinary professional engineer is likely to do it, because he will not be sufficiently familiar with the way in which the older theories are constructed: they must serve as models. Moreover, unlike these older theories, an adequate formulation of electromagnetic theory must, I believe, take account of the special theory of relativity, even though in most cases of engineering importance relativistic corrections are negligible. But the art

of formulating a theory in its simplest form lies in an appreciation of the precise point at which approximations should be introduced. There, then, is a noble goal for the engineer-mathematician—electromagnetism on a post-card.

And now I want to close with a suggestion. Twenty years ago many would have regarded as fantastic the idea of an Institute for Advanced Study, in which scientists of the first rank might devote themselves to academic research. But it exists. In fact, the very evils of American education—low academic standards and a tendency to place universal mediocrity above individual excellence—these evils have produced by reaction a unique institution in which the United States leads the world.

In this country where fairy-tales come true, I want to make a similarly fantastic suggestion, namely, the foundation of an Institute for Elementary Study. As I see it, the university situation for the student of exceptional merit on this continent is bedevilled by the terribly low standard of attainment in the high-schools, where the *average* rather than the *exceptional* comes (and I suppose must come) first. It is galling to think that a Kelvin or a Maxwell may be born every five years in this country of 120,000,000 inhabitants, but that he is selling bonds or directing a corporation or otherwise prostituting his genius just because he did not receive at an early age the fillip necessary to put him on his true scientific path. As long as the man in the street thinks that an inventor of ingenious gadgets is necessarily a great scientist, it is not hard to see that genius may be wasted in this way.

My fantastic plan is this. First arouse the interest of an enlightened millionaire who knows something of the history of science, the early age at which mathematical genius matures and the essentially individual character of great mathematical achievement. Let him endow an institute which would accept by open examination over the whole of the United States ten boys of the age of twelve each year. The crucial part of the examination would not be, like most examinations, a test of knowledge: it would be a test of the rapidity with which a boy could seize a new mathematical idea. The selected group would be kept at the expense of the institute, and would receive the finest possible instruction in the mathematical sciences in a wide sense. Those who did not show a keen passion for mathematics and noteworthy ability would be sent back to ordinary schools none the worse, and the small group emerging from the institute at the age of eighteen would already be well in advance of many of those graduating at present from the universities. They would be just entering on that age at which mathematical powers are at their height in men of genius. They would have avoided the drill and drudgery that kills in so many the passionate desire to

push forward individually. Entering professional schools of engineering, or pursuing advanced courses in pure or applied mathematics, such young men would have the inestimable advantage of starting with a wide general knowledge of mathematics.

I think that if you will compare the secondary education of the United States and Canada with that of England, and contrast the mathematics covered here with that covered there by boys of exceptional ability, you will see that some such plan as this is not quite as fantastic as it sounds. Is it not true that much of the stimulation of research on this continent has been in the direction of adding to the top-story weight which the foundations are not strong enough to bear? Young men specialise in narrow fields because they have not the wide general knowledge necessary to enable them to do otherwise. What we need to prevent the disintegration of the mathematical sciences, and in particular to bridge the gap between the engineer and the mathematician, is an earlier start and more attention to the boy of exceptional mathematical ability. In fact, the seed from which the engineer-mathematician is to grow must be fertilised in the high-school rather than in the seminar.

THE MAKING OF INDUSTRIAL PHYSICISTS *

By JOHN MILLS

Director of Publication, Bell Telephone Laboratories

Introduction

In the meetings of technical societies the reading of a paper is usually followed by its discussion from the floor. As that peters out the chairman calls upon the author to answer the questions and meet the objections which have been submitted. It is a necessary procedure but one which sometimes leaves a wrong emphasis. The flood-tide of the paper is diverted into bayous of digression and detail.

For attempting a different order there is a literary, if not a scientific, precedent. In "Fanny's First Play," you remember, Bernard Shaw included the dramatic critics among the characters of his drama and into their mouths put their expected criticism. This paper risks a similar departure from the mode. It starts with the remarks by which its author would close its discussion; and these attempt cognizance of questions which might be thought but not expressed.

Concluding Remarks by the Author

In answer to the first question: this paper is merely and entirely the individual opinion and expression of its author. It is derived from many years of interested observation, supplemented by some gossip and pointed by unconscious prejudices. The data upon which its generalizations are based were limited to no single locality or organization.

To the next question: Yes, intellectual curiosity is the prime essential in the mental make-up of a research worker; and my earlier paper,† entitled "Selecting and Placing College Graduates in Business," placed that quality first on the list of requirements.

* A paper delivered at the Physics Conference of the S. P. E. E., Cambridge, Mass., July 1, 1937.

† American Management Association, January, 1925. Annual Convention, New York.

In the present paper, however, I prefer to stress another and broader attribute.

Another question raises a more delicate point. Perform a simple experiment. See how many names of industrial scientists you can write down in thirty seconds. You will probably find that more than half those you have listed are important executives. Since of these less common but well known individuals I am inclined to say "nascuntur non fiunt" the first quarter of my paper is concerned with differentiating between executive and scientific worker. Similar grounds for such a distinction appear to obtain in government bureaus,* endowed foundations and academic institutions as well as in industrial organizations.

The Paper

Before attempting to discuss the making of an industrial physicist, let us consider his un-making. At the start of his work in a large organization a young scientist has ordinarily no supervisory or executive responsibilities. When he proves his worth and assistants are added unto him he assumes a modicum of such responsibility; and, of necessity, he devotes somewhat less of his time to individual creation and production. In his experimental work he does more of planning and interpretation but less of manipulation and calculation; and, if he is as capable as we are assuming, there is a gain in his scientific production. In that happy concatenation of personal ability and expanding opportunity which spells success our hypothetical scientist may gradually come to direct so many and such varied investigations with so many workers that the organizational duties of his position overwhelm the scientific. His planning becomes broader in its outlines, with less attention to details. His judgment and critical faculties are applied more frequently to problems of selecting men than to those of devising physical techniques. The close direction and continuous contact with the laboratory is delegated to two or three assistants who are following the same path of promotion as he himself so recently trod. His own time comes more and more to be expended on the liaison relationships of his department with the other departments in his functionally organized company. He must expound its accomplishments, justify its budget of expenditures, guard its sphere of authority and even fight for enlarged boundaries and new places

* "Minutes of Evidence—The Commission of Enquiry on Public Service Personnel," McGraw-Hill Book Co., 1935, pp. 210–215.

in the sun. All this he must do because he has accepted responsibility for assuring opportunities and appropriate reward for the members of his department. All these things he must do and more too, but all, and always if he is to continue to be successful, in a cooperative spirit and within the limitations of the purpose and policy of the company of which he is an executive employee.

Credit his start, if you will, to training in industrial physics; ascribe his analytical abilities to mathematics and the exact sciences; compliment him, and justly, on the organization he has helped to build and recognize that its products are conceived in science and delivered by engineering; but if you would be meticulous in your classification call him a ci-devant physicist. And necessarily so; he cannot experiment himself; he must not invent, because he should not use his confidential knowledge of impending developments or discoveries in the various branches of his department in competition with the scientists who produce them. He should not even join his name in the publication of scientific papers with that of the man who did the creative work. If he publishes at all, and he is frequently under invitation to do so, it must be on the management of endeavor in industrial science, or a philosophical discourse on its social value, or at the most a broad summary of the work of his associates in some particular field. He can lead in his department by question or implication; he can approve or disapprove projected lines of work; hire and fire; promote or demote; praise or reprove; but he must not compete as a scientist with his subordinates for that would be destructive of morale. He must not do so; and, in general, even if he would there would not be time enough in his day because of the pressure of the business and management problems with which he is constantly confronted and because of the drains upon his time and energy through all those outside contacts which his scientific reputation and his company position entail.

This picture of the metamorphosis of an industrial scientist into an executive may lack verisimilitude in minor features; it is a composite picture and fits no single individual. It is introduced as a first step in clarifying the words used in the title of this paper. Before we can discuss adequately "the making of industrial physicists" we must agree in our concept of that particular species. In that species we should not include, I believe, the heads and officers of large laboratories, engineering companies and foundations because these men are engaged predominantly in executive work as

distinct from scientific work. The making of executives presupposes, in general, a different type of raw material. Many of these men, who are thus ruled out of our consideration, previous to these responsibilities, had careers as scientists; but their present positions were obtained and are held by virtue of characteristics and capabilities which they have in common with other leaders and directors of human activity. They seem to be twice blessed, first with the potentialities of scientists and second with those of executives. By virtue of the first and of their scientific experience they can most successfully apply their executive abilities in organizations engaged in scientific or engineering tasks. But it is safe to say that by virtue of their aptitudes for human relationships and business management, even if they had never studied science, they would * in their mature years be found in positions of responsibility in large organizations.

For purposes of this paper, at least, an industrial physicist is defined as one whose work is primarily and almost exclusively on physical problems. Picture him as one whose office is geographically as well as spiritually adjacent to his laboratory. He may have reporting to him a group of scientists, laboratory technicians, draftsmen, calculators and mechanics, but there will be no intermediates between himself and the individual scientists who assist him. It is by reference to the presence or absence of such intermediates that the distinction can be made between scientific work and a subordinate position in an executive hierarchy. For that reason one might even wish that industrial organizations would quit promoting their most creative scientists into subexecutive positions where necessarily their individual productivities must suffer. Just as a penny saved is said to be a penny earned, so a physicist saved may be considered as one made. If industry could devise a formula of titles satisfying to the ego and would remunerate individual scientific accomplishment to a point where

* In this connection I should like to cite as references two earlier papers: (*a*) "Engineering Aptitudes," *Journal of Personnel Research*, Vol. III, No. 6, Oct. 1924; (*b*) "Know Thyself," *The Management Review*, Vol. XVI, pp. 395–399, Dec. 1927. For years, even when not professionally concerned with personnel work, I have been keenly interested in trying to analyse the urges and driving power which make for success. In the case of many executives, I believe, the dominant urge to have been the satisfaction of an enduring and unsaturated personal ambition to be out ahead, to be best in their group, to be number one, to direct rather than to be directed, supplemented by the courage to accept the responsibilities for success or failure which the number one position entails.

that work competed favorably with executive work many a scientist might be saved and perhaps on the whole industry might be the gainer.

Within the limitations of the definition at which we have arrived we are now ready to consider the manufacturing process. First of importance is the specification of raw material. If the wrong material is shaped and processed the product may pass inspection but it will not have the desired life and reliability. Sooner or later it will fail; it won't fulfill the purpose for which it was designed and must be scrapped. I hesitate to illustrate this fact but an adequate discussion requires that I do. From your own acquaintance you can probably cite one or several instances of men passed by all the educational inspectors, up to and including those responsible for doctorate degrees, who later failed as industrial scientists. Was the failure due to the manufacturing process? or to the material which was used? From my own observation I am inclined to believe that in almost every instance the defect can be ascribed to the raw material rather than to the machine.

At this point, as perhaps at earlier points of this paper, I am in danger of being misunderstood. A hasty disclaimer may therefore be necessary before I continue with the development of my thesis. I recognize the social, economic and political obligations of educational institutions. Also I am somewhat familiar with the present day processes by which colleges select their entering students. Neither of these are under attack. Ph.D.'s are taken as an illustration with no reflection upon their training or the standards which they are required to meet at the various stages of their education but because their number is so small that they stand out and each of us can rather quickly run over the list that comes to his mind.

Add to those whom we might think of as having failed as industrial scientists the larger number who started but were easily diverted or enticed into other activities where their peculiar training is only occasionally if ever called into play. Calculate that total, or estimate its percentage of the entire number, and you may agree with me that in a surprising number of cases a long and careful process of manufacture was applied to material which could not or did not stand up; the finished product ceased to perform the function for which it was intended.

Let me hazard an illustration, still in the Ph.D. group. Does

a case come to your mind of a Ph.D from an excellent department of some important university of recognized high standards who not only never engaged in another piece of research but apparently never even wished to do so? Leave out of account those cases where the man took his doctorate primarily because he wanted to teach and because its possession was a requirement for a professorial position; you will still find plenty of illustrations.

There is no moral obliquity in these cases; no question of right or wrong; and no possible censure of individuals or institutions. But nevertheless from the standpoint of making industrial scientists there was something the matter with the material. The candidate, of course, never pretended that he was training for industrial physics nor did the university curriculum claim that it would give such training.

To-day, however, you have paid me the compliment of asking me to discuss the making of industrial physicists. We assume, therefore, that one or more educational institutions wish to set up adequate machinery for such manufacture. In that case the institution must select material suitable to the product it intends to make. The fact that the manufacturing methods of the past have sometimes been successful and sometimes not would lead, I believe, along the lines of our earlier discussion, to the conclusion that some new criterion for material must be established. Ability to pass entrance and other examinations and even the completion of a creditable piece of research, although both necessary, do not appear of themselves to be sufficient.

The human material for the construction of an industrial scientist may be qualitatively described with considerable ease; but to write for it an engineering specification with inspection techniques and with prescribed tolerances is at present impossible. Unless, however, we would credit evolution with having changed human nature within the times of recorded history we will agree that, despite his specialized training, modern scientific point of view and wealth of precise instruments, the industrial scientist of to-day is the man of yesterday and of yesteryear and so on back into prehistoric days. What did this type of human being do in the past? Was he king or priest? captain or explorer? medicine man or scribe? trader or pirate? None of these. He was thinker and craftsman. His was the type that invented the wedge, the inclined plane, the lever and the screw. He surveyed and built the Pyramids; designed and constructed triremes, roads and aque-

ducts; shaped the tools of his day; and led the way from stone to bronze to steel.

His urge was the instinct of workmanship, a pleasure in the act of creation or construction which is its own reward. Neither driven by acquisitive instinct nor maddened by lust for power or fame, his satisfaction was his work; he sought little reward; and died unknown. More practical than the philosophers; spending little of his time in teaching or writing; and no follower of the Muses, he burned with a quiet steady flame of the same divine fire that suffused the great teachers and poets of his time. The captains and the kings depart; but what he wrought is the hidden basis of our material grandeur.

The instinct of workmanship is the dominant urge of creators and craftsmen, of Newton and Faraday, of Leeuwenhoek and Herschel. When modulated by a current of self-expression it produces poets and artists and musicians—Shakespeare, Wagner, Leonardo daVinci and Michael Angelo, and a myriad of lesser lights. Unaffected by it were Croesus and Alexander, the Great, for it does not lead to riches or power. Like virtue it is all too often its own reward. Without it man is aggressive, acquisitive and destructive. With it even an ambition which threatens may be tempered to a social value; for it harmonizes well with all the instincts except that for ruthless acquisition and its own antithesis, destruction.

When the raw human material is not strongly activated by the instinct of workmanship, do not try to manufacture an industrial scientist. You can't make an industrial scientist out of a bond salesman. When the temperamental demands of ambition or of ego-satisfaction are too large, do not expect your product to have a long life; it may undergo a transformation and may turn into anything from a public speaker to an executive, depending upon the environment to which it is exposed. For a reliable product of long life select material of proper instincts and hope that when it has been manufactured it will be employed in a favoring atmosphere.

Behind the persiflage of the preceding paragraph lies my sincere conviction that a strong instinct of workmanship * is the first and necessary requirement for an industrial scientist. Society needs his services. They are vital to nationalities. And educa-

* For the concept of that instinct one is, of course, referred to Thorstein Veblen, "The Instinct of Workmanship," Macmillan, 1914.

tional institutions should take pride in his training; but training alone will not make him. Let any student who wishes register for that course but unless he is marked by the necessary instinct do not assume that he can become an industrial scientist. He will either fail or move on or out.

It has been noticed, of course, that despite the title of this paper I have tended to speak of scientists instead of physicists. This is because most of what I have said need not be so limited and in fact applies to all constructive and creative workers. It is also because the difference between physicist and chemist is not large and should be less. When the former has the organic chemistry which he needs and the latter the electricity which he ought to have the difference will be more nearly one of historical background alone.

For the determination of the presence in any individual of the instinct of workmanship this paper presents no psychological test. Nor does it enter into argument with psychologists as to the existence of this or other instincts. It uses the term as a matter of convenience to denote a common characteristic of the more productive and creative members of the human race. To the author it has appeared from his scrutiny of several hundred individuals, that much could be explained upon the assumption of a driving force compounded of three instincts, one that of workmanship as already described, one for the acquisition of the material things of this world, and the third for the ego satisfaction of credit and acclaim, whether by one's peers, by the masses or by one's conscience or his god.

To illustrate, and at the same time to clarify somewhat the concept of the instinct of workmanship, imagine that there lie upon your desk some morning three distinct projects awaiting your attention and calling for an allocation of your time and energy. Of one project it is obvious that its successful completion would tend toward an increase in your annual income. In another case the reward would be, as Horace described his own fame, a monument more enduring than eternal bronze. In the third, completion would be unrewarded by money and your accomplishment unacclaimed but the task is peculiarly the sort of work you like to do. Assume equal difficulty and energy requirements for the three projects and estimate the relative strengths of their appeals to you.

Or phrase the question differently. On the basis of your present income and the demands upon it set down the somewhat enlarged figure which would mean financial ease and freedom from

irking limitations. Assume that this desideratum in income will be assured to you for years provided that your production does not fall materially below its recent average. Now tell what will keep you up to higher effort. Will it be the desire for still more money and the things it will buy? Will it be the hope of credit and higher rank or authority? Or will it be the pure fun of accomplishment, your play instinct at work, creation and production for their own sake?

In this form, perhaps, the question is not as absurd as it might at first appear. In the faculties of large colleges, where salaries are more or less fixed for professors and promotion in a department is blocked during the life of the incumbent head, you find a situation similar to the hypothetical one of the last question. Run over the wide list of your professorial acquaintances and see if several do not come to mind who seem to have stopped growing, who carry on their annual routines but go no further. The same thing, of course, can be observed in civil service departments. Some men slow down when the acquisitive instinct is blocked in outlet. They become examples to be cited by those who believe that the economic urge is all important in human affairs.

But look again and you will find some who strive for fame. Sometimes they get it through publication and sometimes only within a narrow circle of observant colleagues. Others, apparently without thought of credit, do more and better work each year, accepting added tasks for the sheer pleasure of accomplishment, for the momentary satisfaction of an enduring instinct of workmanship. Where the dominant urge is for recognition or for self-expression you may find the man's most noteworthy accomplishments, or those in the credit for which he takes most pleasure, are avocational and outside his immediate job. Where the instinct of workmanship is effective the job is likely to be an end in itself, and to supply full opportunity for satisfaction.

A man's success in a vocation depends, of course, upon four factors: innate ability, motivation, training and opportunity. The intensity and persistence with which he employs his talents, and whether or not he wraps them in a napkin and preserves them unused, are determined by the character and degree of his motivation. Without adequate driving force innate ability is futile, training is a non-dividend paying investment and opportunities pass unaccepted.

Anyone who ever won a Phi Beta Kappa key or that of Sigma

Xi can look back upon his academic work and remember at least one occasion when some zealous faculty proselyter for his department's courses suggested on the basis of apparent ability the opportunities in his field. I remember quarreling a few years ago with the dean of a prominent university who told me with pride that he had three applicants for a vacant instructorship all of whom had had straight A grades in all their college and graduate courses. From my point of view I would have preferred a man who had exercised some engineering judgment on the curriculum, doing only passing work in some of the subjects less important to his career but superlative work in his chosen field. But what I should most have liked to know about any candidate would have been what he had to do to be happy, what inferiority complexes would drive him to compensations—like the defects of speech of Demosthenes—and, since the position was in a laboratory science, how strongly motivated he was by the instinct of workmanship.

Bright students, the upper quarter of a college group, are deceptive in their abilities; they can, if they try at all, do so well in the general and earlier courses of several different subjects. Because of this ability their registrations are either actively sought or passively hoped for by various departments. The students, on the other hand, despite orientation courses and other valid mechanisms, tend to choose their lines of training on the basis of early prejudices, of momentary successes, of their information as to the market for particular skills and of a half dozen other fortuitous reasons.

Someday there must be found a way of getting through the barrier of non-essentials and approaching an inner truth as to a student's necessities. Our academic system wastes its efforts when it trains the wrong man for the right job. Inasmuch as our future depends in large part upon continued and increased scientific production, and hence industrial physicists are a social necessity, we need to select with great care the raw material from which to make them. And in the material there is no element of greater importance than the instinct of workmanship.

TRAINING ENGINEERS IN THE ART OF HUMAN RELATIONS *

By F. ALEXANDER MAGOUN

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I. Need for Such a Course

The older we grow the more clearly we realize the necessity for knowing how to get along amicably with other people. Indeed, ever since Adam put the blame on Eve for his having bitten into the apple of the Tree of Life, the basic problem of all problems has been that of human relationships. Yet it is a problem we have only half tried to solve. The unhappy state of the Occidental world testifies to the breadth and depth of our offense in slighting the subject. Western civilization has been conspicuously advanced by the influence of science and technology, but this brilliant progress has been accompanied by the most violent and blood-letting behavior of all history.†

The opinions of the leaders of industry and their dissatisfaction at the dehumanizing effect of education based solely on the reactions of dead matter, testify to the need for better attention in our curricula to the lifelong task of dealing with other human beings.‡ From this there are no vacations or diplomas of graduation. Even the engineering pedagogues themselves are occasionally crying in the wilderness.

"When I picture the engineer's influence in modern society," says Professor Doan,§ "I see an energetic surgeon operating upon the social organism. He is skilled in the use of instruments but generally quite ignorant and unconcerned about the nerves and endurance of his suffering patient. His one-sided interest in tools and techniques begins in the engineering college where his teachers are content if he learns technology."

Clearly we have been looking at the importance of human re-

* Presented at the 45th annual meeting, S. P. E. E., Cambridge, Mass., June 28–July 2, 1937.

† Sorokin, Pitirim A., "Social and Cultural Dynamics," Vol. III.

‡ Lewisohn, Sam A., "The New Leadership in Industry," pp. 84–109. Merrick, F. A., Address at the dedication of the new Engineering Laboratory at Lehigh University. Spooner, T., "Characteristics of a Group of Engineers," *Electrical Engineering*, Vol. 53, No. 12, December 1934, pp. 1571–1576.

§ Doan, Gilbert E., "Our Sons Specialize," *The American Scholar*, Summer issue 1937, p. 294, Vol. 6, No. 3.

lations through the wrong end of the telescope. A man whose brains are better than his ability to coöperate is dangerous, and by present standards an informed mind is no guarantee of the ability to coöperate. Seeing the world from the engineering point of view is a vastly different thing from seeing engineering from the world point of view.

No voice is raised against the need of better human relations, but many educators are on the fence concerning the possibility of teaching anything about it at the college level; most educators have not yet even found the fence; and some educators are frankly on the side of the Philistines.

No informed person feels that we know very much about ourselves or about how to teach what little we do know. But surely it is weak to feel that because we know little we should attempt nothing; idiotic to say, "Yes, I see the need, but I'll fall in line when the problem is all worked out." Nothing was ever accomplished that way. It is by attempting the problem that it will eventually be solved.

II. Can Good Method in Human Relations be Taught?

No discussion of this question in its present state of development would be adequate without the name of Elliott Dunlap Smith.* He is not only a great teacher, but a great teacher of teachers. From him all of the rest of us in the field have learned much. He is definitely not trying to teach any smart strategy by which to get one's own way. He is not teaching postulates and rules, but underlying principles. He is interested in using the CIO or the NRA only as they help to clarify a principle which will still be useful long after the NRA is forgotten.

The value of any course is not so much in what you study as in whom you study under. This is particularly true in humanics where character, interest, experience, and capacity to see *behind* the subject are of predominating importance. What the instructor does with what he knows and what he *is* while he is doing it are just as consequential as what he knows. The student will inevitably say, "Don't just tell me what you think; show me what you do." For this reason the teacher of humanics must be no pedantic specialist more deeply concerned with things than with students. He must certainly not be a man whose experience or outreach is narrow, whose mind is crude, or whose sincerity can ever be ques-

* Smith, E. D., Can the Engineering Student be Taught to Manage Men? Journal of Engineering Education, Vol. XXXVIII, October 1930, pp. 99–128. "Engineers, Managers, and Engineering Education," *ibid.*, Vol. XXXIX, December 1931, pp. 846–850.

tioned. You can never really do anything for any student. It is only by *being* something to him that you can influence his life.

It is generally agreed that a formal psychological approach to this subject is sterile and unavailing.* The student's stubborn resistance to psychology unrelated to living is, after all, an indication of his essential mental health. To separate the art of human relations from the fraternity house, from the summer job, and from current problems in industry may be logical, but it is not real. What could be more deadly than a course in human relations which was the corporeal embodiment of mathematical dryness? Ah no! The student should be able to stick a knife into it anywhere and draw blood. The necessary psychology of habits, desires, understanding, attention, or group action should always be taught from the development of actual living problems, specifically and exactly attacked. You cannot teach the undergraduate—or anyone else—very much by vague generalities on the one hand, or by wearisome details on the other. You cannot think unless you have a problem on which to think. The subject matter should always be identified and the problem defined in terms of the student's experience. Properly guided by the instructor he can then really discover the origin and the nature of the problem, and discern those resources and methods which apply to the solution.

No amount of instruction can replace actual experience, but this is true of everything. Life is the only real school master. What we are trying to do is to shorten the time required to learn the lessons of life. To do this effectively the instructor not only needs to have had actual experience in handling problems in human relations; he needs to be able to interpret and to dramatize that experience. A corpse gets little education out of a trip to Europe.

The student's experience is of course inadequate for him to understand the truth, and his understanding of the truth is not sufficient to explain his experience. But he learns much in trying to acquire both, particularly where the instructor is skillful in presenting to his class experiences which are not mere disjointed chaos, but which teach something.

The student is always invited to share the class discussion, not in the hope that he will agree with the professor's judgment, but that he will be lured into doing some vigorous, systematic, independent thinking of his own. Occasionally he will pick up a point which the professor missed entirely. The subject matter is thus not an axis of revolution but a port of adventure.

This kind of instruction requires more mature and qualified

* Report of Informal Conference held at the home of Sam Lewisohn, March 28, 1931—"Teaching Engineering and Business Students to Deal with Men and Manage Industrial Relations," p. 16.

teaching than any lecture-recitation course. The professor must know the field thoroughly, since he can never anticipate where the discussion may turn. Also he must be expert enough to prevent wasting the hour on fruitless and vague side issues, and at the same time never merely follow an outline of his own or get lost in easy generalizations.

"If the student reaches a wrong conclusion by unsound reasoning he can be led to a better conclusion by further experience and better reasoning. But if he were taught to reach a conclusion by blind imitation, neither better reasoning nor more experience could change his stubborn grasp on a belief he knows not why he believes." This explains why no one can have real character without intelligence.

To many a man the most stimulating intellectual experiences he had at college were the bull sessions that lasted till two A.M. They dealt with vital human problems, but unhappily there was no semblance of good method in the approach, and usually nobody in the group really knew what he was talking about. All were groping in the dark to find how incoming experience directs outgoing behavior. Now bring this same thirst for the answer to some of life's inescapable problems into the classroom. Let the problem take shape, not by "one way" lecturing, but by a web of interweaving ideas where the professor is the shuttle carrying the thread according to an orderly process that is good method, and where the interplay of individual differences of opinion forms the warp and makes the pattern. Let the subsequent assignments be undertaken in teams of from three to five students who carry on an outside discussion which is the bull session raised to some exponential function. Let the written fruits of this discussion be corrected—not just graded—by the instructor. This begins to nurture those habits of growth which are the aim of all good teaching,* and which are vastly different from the usual plan of studying only when and as directed.

By doing their assignments in teams the boys soon discover that no two minds react alike. They acquire at least a little tolerance for the opinions of others. They get an extra dividend out of making the lazy members do their part or preventing the domineering ones from dominating the group. Best of all, they experience something of the achievement of coöperative methods which will avoid the difficulties Jones fears and at the same time offer the advantages Brown suggested. Here is actual realization that leadership connotes organization and organization requires coöperation. Here is the beginning of the knowledge that approaching a

* Magoun, F. A., "The Aims and Techniques of Teaching," JOURNAL OF ENGINEERING EDUCATION, February 1936, pp. 452–462.

problem from the other fellow's focus often gives startling results. For instance, whether or not duck hunting is fun depends upon which end of the gun you are on.

To my thinking the finest contribution Smith has made to the teaching of good method in human relations is his class demonstration: the bringing of actual situations into the classroom, such as disciplining a workman (who comes in from the outside and is paid in accordance with the reality of his performance). Usually such situations are handled by the students. Always they are post-mortemed by the professor.

To illustrate the technique, here is one of my own problems. Maxwell himself took part, with two students acting as the superintendent and the master mechanic respectively. They had two weeks in which to prepare, but did not meet Maxwell until the appointed day. The whole performance was spontaneous. No one of the participants acted a pre-conceived part, but everyone tried to be natural and to use good method in thinking the problem through.

The instrument repair man in the Lavoisier Chemical Works is a young engineering graduate by the name of Maxwell. For the past two months his job has been made more difficult by extensive alterations which are interfering with operating conditions.

Last month the control mechanism of an electric recording and control flowmeter was out of order, but the recording part of the meter was not affected. Unknown to Maxwell, about 10:00 A.M., Mr. Gilbert, the chief electrician, removed the fuses from the circuit controlling both parts of the instrument, intending to have one of his men repair the control mechanism. At 11:30 A.M. the test engineer for the contractor asked Maxwell to put the recorder in operation. He found the fuse out; but because no one was working on the circuit and there were several fuses lying beside the switch box, he complied with the engineer's request.

After a delay caused by an emergency elsewhere, an electrician unsuspectingly went to work on the control mechanism, about 2:30 P.M. The supposedly dead circuit gave him a shock of 110 volts and so startled him that he lost his balance. Falling four feet, he struck his head against a pipe; but fortunately he was only knocked unconscious.

Mr. Gilbert upbraided Maxwell, who resented it for a number of reasons:

(1) The chief electrician was not his boss.
(2) He had not been told that the control mechanism was to be repaired.
(3) At 11:30 no one was working on the line.
(4) There was a better way to disconnect the control mechanism from the meter. Wing nuts on the back of the instrument panel were provided for the purpose.

During the conversation the superintendent was standing near by, but had nothing to say.

Two days ago Maxwell's boss (the master mechanic) ordered him to repair the counter on one of the punch presses in the machine shop. At the same time Maxwell was shown a letter from the Murdoch Instrument Company saying that their man would be at the Chemical Works early yesterday morning to install a new Venturi Meter in the Feed-water line of boiler No. 4.

But somehow Maxwell was not there when the Murdoch representative came at 10:30 A.M. Instead, he was repairing the counter. Since the check valve leaked, the Murdoch workman closed the stop valve at the boiler in order to keep water from backing up in the pipe. When the job was finished, he forgot to open the stop valve. As a result, when the boiler feed pump was started, the vanes merely churned the water about instead of driving it through the feed pipe. The boiler went dry, burned a fusible plug, and caused a serious loss of power in the factory until the boiler could be put back on the line. The licensed fireman knew that boiler No. 4 was down in order that the old meter might be replaced. He should have inspected the valves before firing the boiler, but did not. The Murdoch man should have, and Maxwell—had he been there—would have asked the fireman's permission to close the stop-valve.

This morning the superintendent and the master mechanic decided that before any disciplinary action was taken they should hear what Maxwell had to say for himself.

Handle the case from this point on.

Things left to themselves always tend to take the form of maximum disorganization and confusion. Consequently to compel the class to think in orderly, penetrating fashion instead of just to enjoy the demonstration, some such assignment as this always follows:

PROBLEM ON DISCIPLINE CASE

In a period of reorganization the Notquite Mill has determined to make a study of its employees and to weed out the incompetents. What are the principal recommendations you would make to the management as to how to prepare for and how to handle such a program?

I. Make a systematic tabular outline of your recommendations, using concrete suggestions that are specifically applicable, such as "Discover what effect the CIO will have on your program," not just generalities such as—"Divide your approach into main fields."

II. Support your points by evidence taken from the discipline demonstration.

III. Indicate what you think are the main psychological foci such as mental habit patterns, rebellious revery, or fundamental desire.

I am well aware of the generally held opinion that this pedagogical technique succeeds only in the hands of an Elliott Smith. With such a conclusion I do not agree. The question is not, can we use it as effectively as he? (We cannot.) The question is, can we do a better job in our own teaching by using it?

There are things to be learned through observation that can never be learned by word of mouth. What cannot be expressed in

words alone, can never be learned from words alone. Observation is the very essence of the scientific approach; why neglect it where good method in human relations is the goal?

And there are the students who actually take part. To talk about a problem may be intellectually stimulating. To observe it in process is better. But to act in the situation, even ineffectively, is to realize subtle relationships which can never be described. Learning is proportional to the intensity of the experience; not to its duration. Actually dealing with a situation is a far cry from the mere absorption of theory.

It is therefore my strong conviction that reality in human relations can be produced in the classroom by selecting carefully problems that are real, and occasionally by using in connection with them demonstrations that include qualified people from industry who were actually a part of those problems. In the discussion hours the student has been given a body of knowledge. In the demonstration hours he not only has a chance to see or actually to use what he has learned; he reaches skill through a growing awareness of relationships between theory and practice. He does some serious thinking as a result of his body of knowledge, and is therefore on the road to wisdom. We cannot, of course, "make wise the simple." Training does not make a better eye or ear; it only develops the organs one already has. Similarly education only increases the material a mind has for use and the ability of that mind to use it—when there was a mind there to start with.

III. What Constitutes Good Method in Human Relations?

Without being assembled constructively, building materials are useless and trivial. In the same way, good method in handling a problem in human relations must have structure.

By good method I do not mean any stereotyped form or ready-made procedure by which to behave in set circumstances. It were better to teach nothing than to teach any artificial straight-jacket of conduct. By good method is meant the following of a basic substructure of sound principles, which are deliberate in development but spontaneous in expression; the application of skilled intelligence according to a fundamental plan. A stereotyped form would be, "Connect wire *A* to the positive pole of the battery." Good method is "Connect the wire to the proper terminal for your purpose." A stereotyped form would be, "State the facts first." Good method is, "Get the facts understood first, and to get them understood you may have to begin somewhere else."

The common denominator of all science and of all art is good method. Consequently it should be particularly easy to instruct the engineering student in the art of solving intense human problems.

The philosophical technique is similar to what he has been taught in the laboratory: i.e. to gather and classify his data, testing them for validity, completeness, reliability, objectivity; to analyze the significant data in terms of his problem; to use this analysis in his how to meet a similar problem next time. A course in humanics should be based on the use of exactly this method of attack.

OUTLINE FOR ATTACKING A PROBLEM IN HUMAN RELATIONS *

STAGE I PREPARE

(*A*) Discover and eliminate any bias
(*B*) Make a bilateral approach
(*C*) Discover significant facts
Recognize assumptions
(*D*) Consolidate and check fundamental problems and criteria

STAGE II ANALYZE

(*A*) See the problem as a whole
Facts now boiled down
(*B*) Determine the focus of the problem
(*C*) Contrive a total solution
Check satisfaction of conditions and original problem

STAGE III HANDLE

(*A*) One step at a time
Let each step be well understood before giving attention to the next
(*B*) Recheck solution between steps

STAGE IV EVALUATE

(*A*) Review the entire case
(*B*) Write out its lessons

STAGE V MAINTAIN

(*A*) Provide structural organization and checks
Supporting relationships
Systematic follow-up

Of these five steps, the one which most needs emphasis is PREPARE. Problems set before us for solution in school invariably come already prepared with the result that, lacking better train-

* Except for a few changes this outline belongs to Elliott Dunlap Smith of Yale and is here used with his permission.

ing, all of us have a propensity for attacking our problems in human relations by jumping into HANDLE. And we are prone to proceed, by way of our emotions, to seek immediate outlets rather than to think in terms of long run consequences.

When lost in the woods and faced with the task of finding a way out, the last thing to do is to begin thrashing about in a frenzy of activity. Solution inescapably involves walking, but first sit down quietly. Cool off. Get control of your emotions. Then begin to gather your facts. Where is the sun? What kind of woods? Is it possible to go down hill until you strike a stream? What sort of path should one look for? How long will daylight last? What things must I do? What dangers can be avoided? What are the immediate and the long run objectives? How do all these factors affect each other?

Then, with a carefully thought out program as a basis, it is possible to act intelligently, but always with an eye for new developments that may necessitate a change of plan. The art of such problem solving lies in the ability to perceive and to concentrate on the significant parts of the question, though they sometimes appear insignificant at first. Science sees multitudinous detail in exact reproduction; art, in a few swift strokes, picks out only the essentials.

To recapitulate, I believe that the need for training in the art of human relations is self evident; that good method—not any body of doctrine—should be the basis of all such training; and that good method can best be taught by men who have had actual executive experience and who stimulate the student into doing vigorous, systematic, independent thinking of his own through the ordered discussion of vital and inescapable problems, and occasionally by the actual handling in the class room of intense human situations. The focus of such a course should always be to train the student in the fundamental characteristics of human nature and in the fundamental problems of human contacts, so that he can and will seek solutions which provide the optimum interweaving of the interests of everyone involved. This is not pointed toward the idea of ego inflating leadership, but toward the idea of accepting responsibility for successful team work. Our teaching has so long been oriented, both by precept, and by implication toward the one idea of individual leadership that it will be a long difficult task for us to change its focus from the circular center of ME to the double elliptical centers of YOU and ME.

I have an idea, to paraphrase Dean Dexter Kimball, that these new concepts of the importance of good method in human relations will yet make a great rattling among the dry bones of education.

INCOME AND EARNINGS IN THE ENGINEERING PROFESSION 1929 TO 1934 *

Reports from 52,589 professional engineers to the Bureau of Labor Statistics, in its survey of the engineering profession, undertaken at the request of the American Engineering Council, make it possible to relate the income data to many aspects of professional engineering activity. These income data are probably the most comprehensive ever presented in regard to a professional group. The following general findings appear from analysis of the reports.

In 1929, 50 per cent of the 30,032 reporting engineers earned more than $3,412, and 50 per cent earned less than that amount. Twenty-five per cent earned more than $5,012 but only 10 per cent had incomes in excess of $7,466 per annum. On the other hand, 25 and 10 per cent of the engineers earned respectively less than $2,509 and $1,878 per year.

Comparison of the incomes for 1932 and 1934 with those reported for 1929 shows that from 1929 to 1934, the sharpest absolute declines occurred in the two higher income groups. Their percentage decreases were least, however, averaging 31.2 and 31.6 per cent, whereas the middle values of income declined by 33 per cent, and the two lower levels by 41.3 and 53.6 per cent, respectively.

Almost two-thirds of these decreases in earned annual income occurred between 1929 and 1932. There were further decreases from 1932 to 1934.

Among the several professional classes, the divergences in earning capacities were most marked in the higher levels of income. Furthermore, the ranking of the profession on the basis of earnings opportunity was the same in the highest 10 and 25 per cent only.

In 1929, without regard to the age distributions of the different classes 10 per cent of the mining and metallurgical engineers earned more than $9,912 per year, chemical and ceramic engineers ranked second with 10 per cent earning more than $9,103, and were followed in order by mechanical and industrial engineers ($8,508), electrical enginees ($7,185), and civil engineers ($6,507). At the upper 25 per cent level, mining and metallurgical engineers reported earnings of $6,301 per year, and those of the other professional classes ranged from 4 per cent lower for chemical and

* From the *Monthly Labor Review*, August, 1937, of the Bureau of Labor Statistics, United States Department of Labor. Prepared by Andrew Fraser, Jr., of the Bureau's Division of Wages, Hours, and Working Conditions.

ceramic engineers to 28 per cent lower for civil engineers. This order of professional classes was also maintained in 1932 and 1934.

In 1929, the earnings of the mining and metallurgical engineers were highest in the middle and two lower levels of income, while those of the electrical engineers were lowest. At these three levels, the earnings of the former were $4,010, $2,839, and $1,985; for the latter they were $3,277, $2,339, and $1,662. Over these three levels, the relative positions of the three remaining professional classes changed. There were further shifts in 1932 and 1934.

The data also show that, over the period 1929 to 1934, relatively the smallest shrinkages in earnings were reported by the civil engineers, while the chemical and ceramic engineers suffered the greatest cuts. Over the five income levels, the former ranged from 29.0 to 47.2 per cent, the latter from 35.6 to 63.8 per cent.

Analysis of the income data reported by all engineers in 1929, 1932, and 1934 shows that earnings advanced with age in three distinct phases, showing initial periods of exceptionally rapid rise, followed by two others of slower rates of increase. The age spans of these phases varied with the income level.

With advancing age, the spread in earnings became most accentuated beyond the age of 38. Thus, at the ages of 44 and 60, the incomes of the upper 25 per cent differend from the median or middle value by 41.0 and 51.0 per cent. The corresponding incomes of the upper 10 per cent at these ages were greater than the median by 116.0 and 157.0 per cent. Even in 1932 and 1934, this advantage in earning capacity was maintained.

The earnings of the engineers in the lower income levels ceased to increase at a relatively early age. These showed a level period before beginning to decline, whereas the higher levels of income showed continuous increases for a considerably longer period, after which, however, they declined at a much greater rate.

Over the period 1929 to 1934, a rise in earnings occurred for the youngest engineers who were in the profession in 1929 and who were 30 years of age or less in 1934. Thereafter there were progressively larger declines for the older engineers.

Comparison of the earnings of engineers of identical ages in 1929 and 1934 shows that the average income of engineers who had been out of college for 2 years declined 43 per cent. The income of those who had been out 5 years declined 35 per cent. For older engineers the decline approximated 30 per cent.

Consideration of the incomes reported by engineers of different educational backgrounds shows that those with a formal engineering education did receive a higher income. The differentials in

earnings, however, did not accrue in equal measures for all five professional classes.

At about 28 years of age the "other" engineers had lost an initial advantage in earning capacity. At that point, the 1929 earnings of the graduates ranged from $2,725 to $3,000 per year, and those of the corresponding "other" engineers from $2,430 to $2,650.

With advancing age, the spreads in earnings in favor of the graduates became very marked indeed. For example, at 5, 20 and 37 years after graduation, the earnings of the first-degree mechanical and industrial engineers exceeded by $175, $925, and $1,322 per year those of the engineers of the same professional class whose college course was incomplete, and surpassed by $225, $1,160, and $1,815 per year those of engineers with a noncollegiate technical school education.

Even in the graduate groups there was variation in the increase in earning capacity among the several professional classes. Thus, the 1929 earnings of first-degree civil engineers who had been out of college for 5 years were only $2,050 less than the earnings of those who had graduated 30 years before, whereas the corresponding difference for chemical and ceramic engineers was $3,600. The ranges in earnings of the remaining graduate groups fell between those reported by the civil and the chemical and ceramic engineers.

In general, the earnings of the "other" engineers ceased to increase at an earlier age than those of the graduates.

CIVIL ENGINEERING DIVISION

L. E. GRINTER

One of the projects initiated by the Civil Engineering Division last year was the organization of a Committee on Library Facilities, which will undertake to compile a list of important books for an acceptable Civil Engineering Library. The intention is to list only books and pamphlets which are of particular value. The initial list will probably consist of about 500 titles, but this number may be extended if the first list serves a useful purpose.

In order to obtain an unbiased choice of titles, it was decided to make use of a very large committee. Hence the skeleton committee outlined below will be extended by the appointment of subcommittees for each topic listed. Each member of each subcommittee will prepare his own specialized list of books and from these many lists the final groups will be drawn together.

If the work of the committee is to prove entirely successful, the subcommittees must be composed of the best qualified men in each specialized field. Hence we are asking that you accept whatever responsibility may come your way in connection with this important program. The work will be so thoroughly subdivided that no one man will need to devote more than a few hours time to his assignment.

Division Chairmen	Subdivisions
Frank Kerekes (Structures)	Elementary Theory Indeterminate Structures Structural Design Reinforced Concrete Wood Structures Fabrication and Erection Foundation Structures Miscellaneous Structures
F. L. Plummer (General)	Mechanical Drafting Structural Drafting Handbooks Plain Concrete Materials of Engineering Soil Action Roads and Pavements Bituminous Surfaces
F. T. Mavis (Mechanics and Hydraulics)	Theoretical Mechanics Strength of Materials Elasticity Testing Materials Hydraulics Hydrology Irrigation, Drainage Hydraulic Machinery Dams Hydrodynamics
Paul P. Rice (Surveying and Mapping)	Plane Surveying Advanced Surveying Geodesy Curves and Earthwork Public Land Surveys Surveys—Historical Railway Location Mapping
H. A. Vagtborg (Sanitation)	Water Supply Sewage Disposal Public Health Industrial Sanitation
E. L. Grant (Administration)	Business Law Contracts and Specifications Engineering Relations Public Management Engineering Economy Cost Estimating Construction Methods and Management Valuation Accounting and Statistics Report Writing

Coordination Committee

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F. L. Plummer

ENGLISH NOTES

DEVOTED TO THE INTERESTS
OF TEACHERS OF ENGLISH
IN ENGINEERING SCHOOLS

J. L. VAUGHAN, EDITOR

THE "ORAL REPORTS" COURSE AT GENERAL MOTORS INSTITUTE

For a considerable period of time it has seemed to us at General Motors Institute that some of the advanced speech work for engineering students could be utilized, in part at least, for the purpose of acquainting the students with industrial and engineering periodical literature.

With these thoughts in mind we organized three years ago a one-semester course in the junior year with the following objectives:

1. To provide further experience in public speaking.
2. To provide opportunity for preparing abstracts to be presented orally.
3. To acquaint students with industrial and technical periodicals.

Before entering "Oral Reports," the student has a semester of public speaking so that this course provides further training and at the same time introduces him to a new type of material.

Some of the reference work is done in such periodicals as *Factory, Mechanical Engineering, Machine Design, S.A.E. Journal, Metal Industry, Diesel Power, Metal Progress, National Safety News, Personnel Journal,* and *Heat Treating and Forging.* Through *The Engineering Index* and *The Industrial Arts Index* he may find additional information on any subject selected for discussion.

Each student prepares an abstract of the article or a composite abstract of several articles and presents the material to the class orally. The situation is not unlike that of a seminar in that each student pursues, for the time being, a specialty in his reading and brings to the group a summary of his findings.

During his report he makes free use of the blackboard, sketches, etc. Notes are used sparingly, usually for statistical information only. While he is reporting, the student may be interrupted for questions from the audience.

After the student has prepared his material for presentation, he files with his instructor a 4×6 card which gives the topic of the report, the date of the report, the main points in his outline, his references, and his name. On the reverse side of the card is space to be checked by the instructor during the progress of the report.

We are interested in his way of opening the report, the clearness with which he states his objective, directness, delivery, organization, and his conclusion. Other matters checked include his use of illustrations on the blackboard, use of notes, and skill in answering questions. A space at the bottom of the card is left for suggestions for improvement.

After three years we can report that the course has had some success. The student undoubtedly gains confidence in speaking before groups who may at any time challenge his facts. In addition, he becomes familiar with periodicals in his professional field. He learns their contents, their merits, and

their faults. He learns to evaluate them and has a fair idea of the ones to which he will subscribe after he leaves school. Not the least of the merits of the course is that it develops the habit of reading engineering magazines while the student is in school. Some of the men who have graduated have told me that they began to read these periodicals in the course and that they have continued to follow engineering progress ever since. This alone, it seems to us, would be ample justification for a course in "Oral Reports."

C. A. BROWN,
Head of the Department of English

COLLEGE NOTES

Northeastern University.—*Faculty Appointments and Promotions:* Five additions have been made to the teaching staff of the College of Engineering this fall: two in the Department of Chemistry, two in the Department of Civil Engineering, and one in the Department of Physics. John C. Morgan has been promoted from Instructor to Assistant Professor of Co-ordination, and Frederick A. Stearns from Assistant Professor to Associate Professor of Mechanical Engineering. All full-time members of the faculty have returned again this year, the only changes in organization being the retirement of Professor William Lincoln Smith as head of the Electrical Engineering Department and the promotion of Professor Roland G. Porter to this position. Professor Smith, who has taught electrical engineering at Northeastern for over forty years, was guest of honor at a testimonial dinner last spring which was attended by several hundred of his friends and former students. Northeastern University conferred upon him the degree of Eng.D. at the 1937 Commencement Exercises.

The five new members of the Engineering staff this fall are the following:

William Fay Luder, Instructor in Chemistry; A.B., Kalamazoo College, 1933; Ph.D., Brown University, 1937. *Mario Giella,* Assistant-instructor in Chemistry. *Leslie W. Lenfest,* Assistant-instructor in Civil Engineering. Messrs. Giella and Lenfest were graduated from Northeastern University in 1937.

George Baker Welch, Assistant Professor of Physics. He was graduated from Bowdoin College in 1922; Ph.D., Cornell, 1928.

John J. Devine, Instructor in Civil Engineering. A graduate of Rhode Island State College, S.B., Brown University, S.M.

BOOK REVIEWS

Analytic Geometry and Calculus, by MAX MORRIS and ORLEY E. BROWN. First edition. New York, McGraw-Hill Book Co., Inc., 1937. 507 pp. $3.75.

There is a tendency among many, fortunately not all, writers of present day text books to dilute the contents of the course in question. This dilution is frequently explained by the formula, "adaptation of the course to the needs of the student." There is seldom any suggestion that the student should rise to the intellectual exigencies of the course. The present text is a worthy exception to the tendency mentioned. It offers an excellent and substantial course in both analytic geometry and calculus.

The analytic geometry portion of the book occupies 139 pages. Polar coördinates are introduced early. They are happily utilized at once in deriving the formulas for a rotation of axes in the plane, and later (page 52) in obtaining the normal form for the equation of a straight line. A slight knowledge of determinants is assumed in expressing the area of a plane triangle when the coördinates of its vertices are given. Other well chosen instances of the elementary use of determinants in the mathematical economy occur. Some topics belonging to the subject of analytic geometry, for example, pole and polar with reference to a conic, diameters of a conic, and singular points, have been omitted. But there has been no skimping of discussion of those topics selected for inclusion.

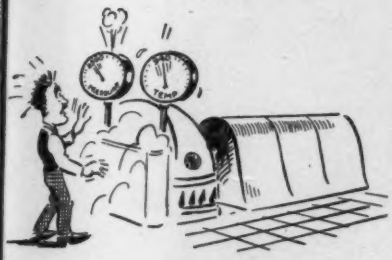
The calculus portion comprises 355 pages. Besides the usual topics, some ordinarily reserved for advanced calculus are taken up, for example, space curves, line integrals, Cauchy's integral test for convergence of an infinite series, and series solutions of certain differential equations. Approximate quadratures are effected by means of formulas due to Gauss and to Euler and Maclaurin. These formulas are novel in calculus texts.

One of the best features of the book as a whole is that many results of a corollary nature which often occur in the body of a text are set as exercises for the student to work. This arrangement helps materially, as the authors point out, to forestall any tendency which the student may have to slight the reading of the text by merely picking out the formulas he deems necessary to solve his problems. The student is thus invited to participate in the development of the course.

The book is carefully written throughout, with reasonable respect for rigor in an elementary course. The problems are numerous and good. The general appearance of the book is attractive.

A. E. STANILAND.

G-E *Campus News*



IT'S THE "TOPS"

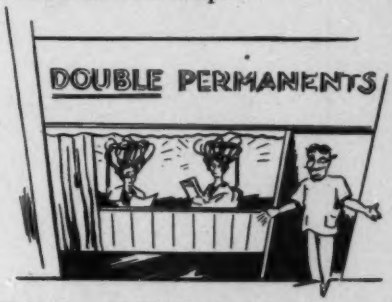
A turbine-generator set now being built at the Schenectady Works of the General Electric Company will operate at a pressure of 2500 pounds and at a temperature of 940 F. This pressure is nearly 1000 pounds more than that used for any other commercial unit now in service, and the temperature is higher.

It represents the work of many men. Experts in mechanical design have solved unique problems—for the shell of the turbine will have to withstand pressures equal to those that exist more than half a mile below the surface of the sea. When the unit is completed, electrical and chemical engineers, metallurgists, and research workers will have contributed knowledge and experience to it.

The design and construction of turbine-generators such as this is largely the work of college graduates—some of whom entered G-E Test only a few years ago. Thousands of other Test men are engaged in the design, manufacture, and sale of these and hundreds of other electric products that are used in industry today.

TWO PERMANENT WAVES

Co-eds preparing for a dance are not the only subjects for permanent waving —there is the tungsten wire used in General Electric lamps.



This wire, 19/10,000 inch in diameter, is first tightly wound, 335 turns to the inch, with the coils 1/1000 inch apart. After the wire receives this first "permanent wave," it is coiled once more, 70 turns to the inch, with 7/1000 inch between the turns. This reduces the original 20 inches of wire to a coil 5/8 inch long and having an outside diameter of 310/10,000 inch.

These permanent waves pay real dividends because tungsten wire becomes more brilliant as it is more closely compacted. This new process is only one of many developments made by G-E engineers in the field of illumination—a field which offers many opportunities to technically trained men.

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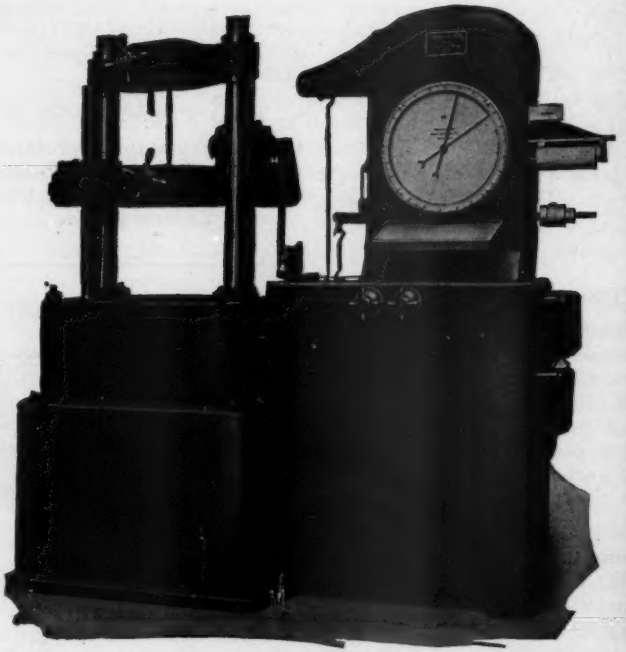

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